MiCOM P44y
(P443 & P446)

Fast Multifunction Distance Protection

P44y/EN M/E63

Version Software Version D0
Hardware Suffix M

Technical Manual

Content This Technical Manual incorporates the P44y/EN M/D52 Technical Manual (Software Version 57/B0, Hardware Suffix K), plus the technical changes from the P44y/EN AD/E63 Update Documentation (Software Version D0, Hardware Suffix M).

Schneider Electric

Note The technical manual for this device gives instructions for its installation, commissioning, and operation. However, the manual cannot cover all conceivable circumstances or include detailed information on all topics. In the event of questions or specific problems, do not take any action without proper authorization. Contact the appropriate Schneider Electric technical sales office and request the necessary information.

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3	Getting Started	P44y_P445/EN GS/F54
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SAFETY INFORMATION

CHAPTER SI

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1 INTRODUCTION

This guide and the relevant equipment documentation provide full information on safe handling, commissioning and testing of this equipment. This Safety Information section also includes reference to typical equipment label markings.

Documentation for equipment ordered from Schneider Electric is dispatched separately from manufactured goods and may not be received at the same time. Therefore this guide is provided to ensure that printed information which may be present on the equipment is fully understood by the recipient.

The technical data in this Safety Information section is typical only, see the technical data section of the relevant product publication(s) for data specific to a particular equipment.

WARNING **Before carrying out any work on the equipment the user should be familiar with the contents of this Safety Information section and the ratings on the equipment's rating label.**

Reference should be made to the external connection diagram before the equipment is installed, commissioned or serviced.

Language-specific, self-adhesive User Interface labels are provided in a bag for some equipment.

2 HEALTH AND SAFETY

The information in the Safety Information section of the equipment documentation is intended to ensure that equipment is properly installed and handled in order to maintain it in a safe condition.

It is assumed that everyone who will be associated with the equipment will be familiar with the contents of that Safety Information section, or this Safety Guide.

When electrical equipment is in operation, dangerous voltages will be present in certain parts of the equipment. Failure to observe warning notices, incorrect use, or improper use may endanger personnel and equipment and also cause personal injury or physical damage.

Before working in the terminal strip area, the equipment must be isolated.

Proper and safe operation of the equipment depends on appropriate shipping and handling, proper storage, installation and commissioning, and on careful operation, maintenance and servicing. For this reason only qualified personnel may work on or operate the equipment.

Qualified personnel are individuals who:

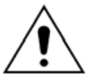
- Are familiar with the installation, commissioning, and operation of the equipment and of the system to which it is being connected;
- Are able to safely perform switching operations in accordance with accepted safety engineering practices and are authorized to energize and de-energize equipment and to isolate, ground, and label it;
- Are trained in the care and use of safety apparatus in accordance with safety engineering practices;
- Are trained in emergency procedures (first aid).

The equipment documentation gives instructions for its installation, commissioning, and operation. However, the manuals cannot cover all conceivable circumstances or include detailed information on all topics. In the event of questions or specific problems, do not take any action without proper authorization. Contact the appropriate Schneider Electric technical sales office and request the necessary information.

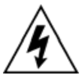
3 SYMBOLS AND LABELS ON THE EQUIPMENT

For safety reasons the following symbols and external labels, which may be used on the equipment or referred to in the equipment documentation, should be understood before the equipment is installed or commissioned.

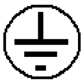
3.1 Symbols



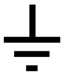
Caution: refer to equipment documentation



Caution: risk of electric shock



Protective Conductor (*Earth) terminal



Functional/Protective Conductor (*Earth) terminal

Note: *This symbol may also be used for a Protective Conductor (Earth) Terminal if that terminal is part of a terminal block or sub-assembly e.g. power supply.*

***CAUTION: The term “Earth” used throughout this technical manual is the direct equivalent of the North American term “Ground”.**

3.2 Labels

See Safety Guide (SFTY/4L M) for typical equipment labeling information.

4 INSTALLING, COMMISSIONING AND SERVICING

Manual Handling

Plan carefully, identify any possible hazards and determine whether the load needs to be moved at all. Look at other ways of moving the load to avoid manual handling. Use the correct lifting techniques and Personal Protective Equipment to reduce the risk of injury.

Many injuries are caused by:

- Lifting heavy objects
- Lifting things incorrectly
- Pushing or pulling heavy objects
- Using the same muscles repetitively.

Follow the Health and Safety at Work, etc Act 1974, and the Management of Health and Safety at Work Regulations 1999.

Equipment Connections

Personnel undertaking installation, commissioning or servicing work for this equipment should be aware of the correct working procedures to ensure safety.

The equipment documentation should be consulted before installing, commissioning, or servicing the equipment.

Terminals exposed during installation, commissioning and maintenance may present a hazardous voltage unless the equipment is electrically isolated.

The clamping screws of all terminal block connectors, for field wiring, using M4 screws shall be tightened to a nominal torque of 1.3 Nm.

Equipment intended for rack or panel mounting is for use on a flat surface of a Type 1 enclosure, as defined by Underwriters Laboratories (UL).

Any disassembly of the equipment may expose parts at hazardous voltage, also electronic parts may be damaged if suitable ElectroStatic voltage Discharge (ESD) precautions are not taken.

If there is unlocked access to the rear of the equipment, care should be taken by all personnel to avoid electric shock or energy hazards.

Voltage and current connections shall be made using insulated crimp terminations to ensure that terminal block insulation requirements are maintained for safety.

Watchdog (self-monitoring) contacts are provided in numerical relays to indicate the health of the device. Schneider Electric strongly recommends that these contacts are hardwired into the substation's automation system, for alarm purposes.

To ensure that wires are correctly terminated the correct crimp terminal and tool for the wire size should be used.

The equipment must be connected in accordance with the appropriate connection diagram.

Protection Class I Equipment

- Before energizing the equipment it must be earthed using the protective conductor terminal, if provided, or the appropriate termination of the supply plug in the case of plug connected equipment.
- The protective conductor (earth) connection must not be removed since the protection against electric shock provided by the equipment would be lost.
- When the protective (earth) conductor terminal (PCT) is also used to terminate cable screens, etc., it is essential that the integrity of the protective (earth) conductor is checked after the addition or removal of such functional earth connections. For M4 stud PCTs the integrity of the protective (earth) connections should be ensured by use of a locknut or similar.

The recommended minimum protective conductor (earth) wire size is 2.5 mm² (3.3 mm² for North America) unless otherwise stated in the technical data section of the equipment documentation, or otherwise required by local or country wiring regulations.

The protective conductor (earth) connection must be low-inductance and as short as possible.

All connections to the equipment must have a defined potential. Connections that are pre-wired, but not used, should preferably be grounded when binary inputs and output relays are isolated. When binary inputs and output relays are connected to common potential, the pre-wired but unused connections should be connected to the common potential of the grouped connections.

Pre-Energization Checklist

Before energizing the equipment, the following should be checked:

- Voltage rating/polarity (rating label/equipment documentation);
- CT circuit rating (rating label) and integrity of connections;
- Protective fuse rating;
- Integrity of the protective conductor (earth) connection (where applicable);
- Voltage and current rating of external wiring, applicable to the application.

Accidental Touching of Exposed Terminals

If working in an area of restricted space, such as a cubicle, where there is a risk of electric shock due to accidental touching of terminals which do not comply with IP20 rating, then a suitable protective barrier should be provided.

Equipment Use

If the equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.

Removal of the Equipment Front Panel/Cover

Removal of the equipment front panel/cover may expose hazardous live parts, which must not be touched until the electrical power is removed.

UL and CSA/CUL Listed or Recognized Equipment

To maintain UL and CSA/CUL Listing/Recognized status for North America the equipment should be installed using UL or CSA Listed or Recognized parts for the following items: connection cables, protective fuses/fuseholders or circuit breakers, insulation crimp terminals and replacement internal battery, as specified in the equipment documentation.

For external protective fuses a UL or CSA Listed fuse shall be used. The Listed type shall be a Class J time delay fuse, with a maximum current rating of 15 A and a minimum d.c. rating of 250 Vd.c., for example type AJT15.

Where UL or CSA Listing of the equipment is not required, a high rupture capacity (HRC) fuse type with a maximum current rating of 16 Amps and a minimum d.c. rating of 250 Vd.c. may be used, for example Red Spot type NIT or TIA.

Equipment Operating Conditions

The equipment should be operated within the specified electrical and environmental limits.

Current Transformer Circuits

Do not open the secondary circuit of a live CT since the high voltage produced may be lethal to personnel and could damage insulation. Generally, for safety, the secondary of the line CT must be shorted before opening any connections to it.

For most equipment with ring-terminal connections, the threaded terminal block for current transformer termination has automatic CT shorting on removal of the module. Therefore external shorting of the CTs may not be required, the equipment documentation should be checked to see if this applies.

For equipment with pin-terminal connections, the threaded terminal block for current transformer termination does NOT have automatic CT shorting on removal of the module.

External Resistors, including Voltage Dependent Resistors (VDRs)

Where external resistors, including Voltage Dependent Resistors (VDRs), are fitted to the equipment, these may present a risk of electric shock or burns, if touched.

Battery Replacement

Where internal batteries are fitted they should be replaced with the recommended type and be installed with the correct polarity to avoid possible damage to the equipment, buildings and persons.

Insulation and Dielectric Strength Testing

Insulation testing may leave capacitors charged up to a hazardous voltage. At the end of each part of the test, the voltage should be gradually reduced to zero, to discharge capacitors, before the test leads are disconnected.

Insertion of Modules and PCB Cards

Modules and PCB cards must not be inserted into or withdrawn from the equipment whilst it is energized, since this may result in damage.

Insertion and Withdrawal of Extender Cards

Extender cards are available for some equipment. If an extender card is used, this should not be inserted or withdrawn from the equipment whilst it is energized. This is to avoid possible shock or damage hazards. Hazardous live voltages may be accessible on the extender card.

External Test Blocks and Test Plugs

Great care should be taken when using external test blocks and test plugs such as the MMLG, MMLB and MiCOM P990 types, hazardous voltages may be accessible when using these. *CT shorting links must be in place before the insertion or removal of MMLB test plugs, to avoid potentially lethal voltages.

**Note: When a MiCOM P992 Test Plug is inserted into the MiCOM P991 Test Block, the secondaries of the line CTs are automatically shorted, making them safe.*

Fiber Optic Communication

Where fiber optic communication devices are fitted, these should not be viewed directly. Optical power meters should be used to determine the operation or signal level of the device.

Cleaning

The equipment may be cleaned using a lint free cloth dampened with clean water, when no connections are energized. Contact fingers of test plugs are normally protected by petroleum jelly, which should not be removed.

5 DE-COMMISSIONING AND DISPOSAL

De-commissioning

The supply input (auxiliary) for the equipment may include capacitors across the supply or to earth. To avoid electric shock or energy hazards, after completely isolating the supplies to the equipment (both poles of any dc supply), the capacitors should be safely discharged via the external terminals prior to de-commissioning.

Disposal

It is recommended that incineration and disposal to water courses is avoided. The equipment should be disposed of in a safe manner. Any equipment containing batteries should have them removed before disposal, taking precautions to avoid short circuits. Particular regulations within the country of operation, may apply to the disposal of the equipment.

6 TECHNICAL SPECIFICATIONS FOR SAFETY

Unless otherwise stated in the equipment technical manual, the following data is applicable.

6.1 Protective Fuse Rating

The recommended maximum rating of the external protective fuse for equipments is 16A, High Rupture Capacity (HRC) Red Spot type NIT, or TIA, or equivalent. Unless otherwise stated in equipment technical manual, the following data is applicable. The protective fuse should be located as close to the unit as possible.

DANGER **CTs must NOT be fused since open circuiting them may produce lethal hazardous voltages.**

6.2 Protective Class

IEC 60255-27: 2005	Class I (unless otherwise specified in the equipment documentation).
EN 60255-27: 2005	This equipment requires a protective conductor (earth) connection to ensure user safety.

6.3 Installation Category

IEC 60255-27: 2005	Installation Category III (Overvoltage Category III)
EN 60255-27: 2005	Distribution level, fixed installation.
	Equipment in this category is qualification tested at 5 kV peak, 1.2/50 μs, 500 Ω, 0.5 J, between all supply circuits and earth and also between independent circuits.

6.4 Environment

The equipment is intended for indoor installation and use only. If it is required for use in an outdoor environment then it must be mounted in a specific cabinet of housing which will enable it to meet the requirements of IEC 60529 with the classification of degree of protection IP54 (dust and splashing water protected).

Pollution Degree	Pollution Degree 2 Compliance is demonstrated by reference to safety standards.
Altitude	Operation up to 2000m

INTRODUCTION

CHAPTER 1

Date:	02/2013
Hardware Suffix:	K/M (P44y) and J/L (P445)
Software Version:	55/57/B0/D0 (P44y) and 35/36/E0/F0 (P445)
Connection Diagrams:	10P44303 (SH 01 and 03) 10P44304 (SH 01 and 03) 10P44305 (SH 01 and 03) 10P44306 (SH 01 and 03)
	10P445xx (xx = 01 to 04)
	10P44600 10P44601 (SH 1 to 2) 10P44602 (SH 1 to 2) 10P44603 (SH 1 to 2)

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1 DOCUMENTATION STRUCTURE

The manual provides a functional and technical description of the P443, P445 and P446 distance protection relays and a comprehensive set of instructions for the relays' use and application.

The section contents are summarized below:

P44y_P445/EN IT	**Introduction**	A guide to the range of distance relays and the documentation structure. General safety aspects of handling Electronic Equipment are discussed with particular reference to relay safety symbols. Also a general functional overview of the relay and brief application summary is given.
P44y/EN TD or P445/EN TD	**Technical Data**	Technical data including setting ranges, accuracy limits, recommended operating conditions, ratings and performance data. Compliance with norms and international standards is quoted where appropriate.
Pxxx/EN GS	**Getting Started**	A guide to the different user interfaces of the protection relay describing how to start using it. This section provides detailed information regarding the communication interfaces of the relay, including a detailed description of how to access the settings database stored within the relay.
P44y/EN ST or P445/EN ST	**Settings**	List of all relay settings, including ranges, step sizes and defaults, together with a brief explanation of each setting.
P44y/EN OP or P445/EN OP	**Operation**	A comprehensive and detailed functional description of all protection and non-protection functions.
P44y/EN AP or P445/EN AP	**Application Notes**	This section includes a description of common power system applications of the relay, calculation of suitable settings, some typical worked examples, and how to apply the settings to the relay.
P44y/EN PL or P445/EN PL	**Programmable Logic**	Overview of the programmable scheme logic and a description of each logical node. This section includes the factory default (PSL) and an explanation of typical applications.
P44y/EN MR or P445/EN MR	**Measurements and Recording**	Detailed description of the relays recording and measurements functions including the configuration of the event and disturbance recorder and measurement functions.
P44y/EN FD or P445/EN FD	**Firmware Design**	Overview of the operation of the relay's hardware and software. This section includes information on the self-checking features and diagnostics of the relay.
P44y/EN CM or P445/EN CM	**Commissioning**	Instructions on how to commission the relay, comprising checks on the calibration and functionality of the relay.
Pxxx/EN MT	**Maintenance**	A general maintenance policy for the relay is outlined.

Pxxx/EN TS

Troubleshooting

Advice on how to recognize failure modes and the recommended course of action. Includes guidance on whom within Schneider Electric to contact for advice.

P44y/EN SC or
P445/EN SC

SCADA Communications

This section provides an overview regarding the SCADA communication interfaces of the relay. Detailed protocol mappings, semantics, profiles and interoperability tables are not provided within this manual. Separate documents are available per protocol, available for download from our website.

Pxxx/EN SG

Symbols and Glossary

List of common technical abbreviations found within the product documentation.

P44y/EN IN or
P445/EN IN

Installation

Recommendations on unpacking, handling, inspection and storage of the relay. A guide to the mechanical and electrical installation of the relay is provided, incorporating earthing recommendations. All external wiring connections to the relay are indicated.

Px4x/EN CS

Cyber Security

This section provides details of how to use the Cyber Security features to provide protection against unauthorized disclosure, transfer, modification, or destruction of information and/or information systems, whether accidental or intentional.
The Cyber Security feature is available for these products:

● P445	Software Version F0 and later	Hardware Suffix L and later
● P44y (P443 & P446)	Software Version D0 and later	Hardware Suffix M and later

P44y/EN VH or
P445/EN VH

Firmware and Service Manual Version History

History of all hardware and software releases for the product.

2 INTRODUCTION TO MICOM

MiCOM is a comprehensive solution capable of meeting all electricity supply requirements. It comprises a range of components, systems and services from Schneider Electric.

Central to the MiCOM concept is flexibility.

MiCOM provides the ability to define an application solution and, through extensive communication capabilities, integrate it with your power supply control system.

The components within MiCOM are:

- P range protection relays;
- C range control products;
- M range measurement products for accurate metering and monitoring;
- S range versatile PC support and substation control packages.

MiCOM products include extensive facilities for recording information on the state and behavior of the power system using disturbance and fault records. They can also provide measurements of the system at regular intervals to a control center enabling remote monitoring and control to take place.

For up-to-date information on any MiCOM product, visit our website:

www.schneider-electric.com

3 PRODUCT SCOPE

MiCOM distance protection devices have been designed for the protection of all overhead lines and underground cables where the network is solidly/effectively grounded. For insulated neutral, or Petersen coil earthing, use the MiCOM P433/P435 protection or P439 protection and control relays).

- The P443 is used for single breaker applications.
- The P445 is a high performance relay targeted mainly for sub-transmission and distribution applications. Tripping is three-pole, with a typical operating time 1…1.3 cycles.
- The P446 is used in applications such as breaker-and-a-half, or ring bus topologies, where two circuit breakers feed each line.

Note *The P445 is delivered in a 40TE or 60TE case according to the model selected to allow easy retrofitting.*

3.1 Input Output Configuration

To satisfy different application demands for plant status input and output switching, four models of P443/P445 and three models of P446 are offered with different numbers of opto-coupled digital inputs and relay output contacts as shown in Table 1:

FEATURE	Models P443				Models P445				Models P446		
	A	B	C	D	A	B	C	D	B	C	D
Opto coupled digital inputs (see Note)	16	24	16	24	8	12	16	16	24	24	24
Standard relay output contacts	24	32	16	16	8	12	16	8	32	8	16
High break output contacts			4	8				4		12	8

Notes *For P44y (P443 and P446) models, Software Release B0 - A & B introduces the Enhanced Disturbance Recorder (DR) feature. This increases the number of digital channels to 128 for CB1 and CB2.*
For P445 models, Software Release E0 - A & B introduces the Enhanced Disturbance Recorder (DR) feature. This increases the number of digital channels from 32 to 128.

Table 1 - Input output configuration

3.2 Functional Overview

The P443, P445 and P446 distance relays contain a wide variety of protection and control functions. These features are summarized in Table 2 below:

ANSI	FEATURE		P443	P445	P446
	Dual rated 1A and 5A CT inputs		•	•	•
	Tripping mode		1 or 3-pole	3-phase	1 or 3-pole
	ABC and ACB phase rotation		•	•	•
	Multiple password access control levels		•	•	•
21P/21G	Distance zones, full-scheme protection		5	5	5
	Characteristic	Phase elements	Mho and quadrilateral	Mho	Mho and quadrilateral
		Ground elements	Mho and quadrilateral	Mho and quadrilateral	Mho and quadrilateral
	CVT transient overreach elimination		•	•	•
	Load blinder		•	•	•

ANSI	FEATURE	P443	P445	P446
	Easy setting mode	•	•	•
	Mutual compensation (for fault locator and distance zones)	•		•
85	Communication-aided schemes, PUTT, POTT, Blocking, Weak Infeed	•	•	•
	Accelerated tripping - loss of load and Z1 extension	•	•	•
50/27	Switch on to fault and trip on reclose - elements for fast fault clearance upon breaker closure	•	•	•
68	Power swing blocking	•	•	•
78	Out of step	•		•
∆I/∆V	Delta directional comparison - fast channel schemes operating on fault generated superimposed quantities	•		•
67N	Directional earth fault (DEF) unit protection	•	•	•
50/51/67	Phase overcurrent stages, with optional directionality	4	4	4
50N/51N/67N	Earth/ground overcurrent stages, with optional directionality	4	4	4
51N/67N/SEF	Sensitive earth fault (SEF)	4		4
64	High Impedence Restricted Earth Fault (available on Software 57)	•		•
67/46	Negative sequence overcurrent stages, with optional directionality	•	•	•
46BC	Broken conductor (open jumper), used to detect open circuit faults	•	•	•
49	Thermal overload protection	•	•	•
27	Undervoltage protection stages	2	2	2
59	Overvoltage protection stages	2	2	2
59 Remote	Remote overvoltage protection stages	2		2
59N	Residual voltage stages (neutral displacement)	2	2	2
81U/O/R	A 4-stage underfrequency, 2-stage overfrequency and an advanced 4-stage rate of change of frequency element as well	•		•
50BF	High speed breaker fail. Two-stage, suitable for re-tripping and backtripping	•	•	•
CTS/VTS	Current and Voltage transformer supervision	•	•	•
79	Auto-reclose - shots supported	4	4	4
25	Check synchronism, 2 stages with additional system split detection	•	•	•
	Number of circuit breakers controlled	1		2
	Alternative setting groups	4	4	4
FL	Fault locator	•	•	•
	SOE event records	512	512	512
	Disturbance recorder, samples per cycle. For waveform capture	48	48	48
	Circuit breaker condition monitoring	•	•	•
	Graphical Programmable Scheme Logic (PSL)	•	•	•
	IRIG-B time synchronism	•	(•)	•
	Second rear communication port	•	(•)	•

ANSI	FEATURE	P443	P445	P446
	InterMiCOM teleprotection for direct relay-relay communication. Two scheme types exist, including EIA(RS)232 for MODEM links up to 19.2 kbit/s, and InterMiCOM^{64} 56/64 kbit/s. The latter can be used over direct fiber, or interfaces readily to G.703, V.35, X.21 and IEEE C37.94 multiplexers	•	(•)	•
	High speed, high break (HB) contacts	•	(•)	•
Key (•) denotes optional				

Table 2 - Functional overview

The P443, P445 and P446 support the following relay management functions in addition to the functions illustrated above.

- Measurement of all instantaneous & integrated values
- Circuit breaker control, status & condition monitoring
- Trip circuit and coil supervision
- Programmable hotkeys (2)
- Programmable function keys (10) (P443 and P446 only)
- Control inputs
- Programmable allocation of digital inputs and outputs
- Fully customizable menu texts
- Power-up diagnostics and continuous self-monitoring of relay

3.3 Application Overviews

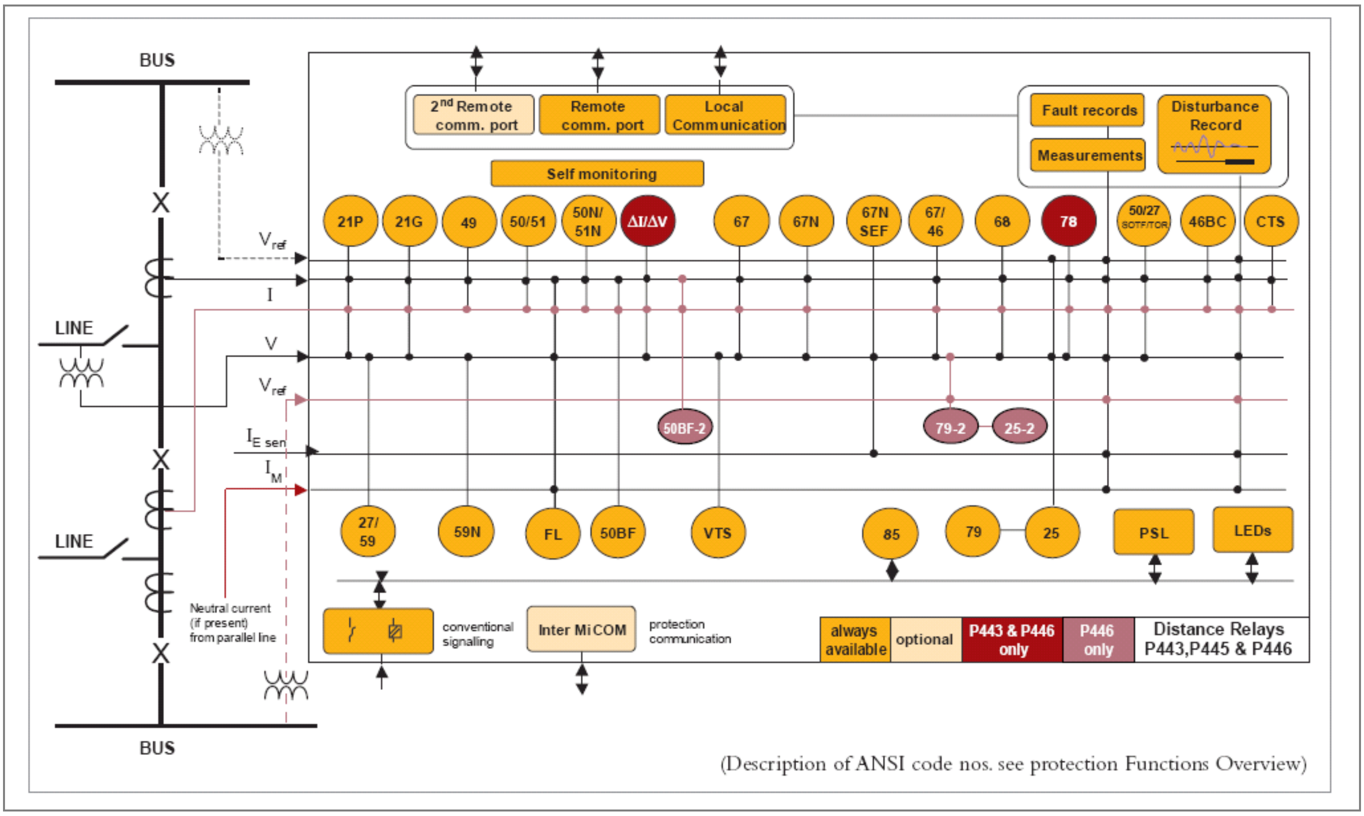
BUS
LINE
LINE
BUS
V_{ref}
I
V
V_{ref}
$I_{E\ sen}$
I_M
Neutral current (if present) from parallel line
2nd Remote comm. port
Remote comm. port
Local Communication
Fault records
Disturbance Record
Measurements
Self monitoring
21P
21G
49
50/51
50N/ 51N
ΔI/ΔV
67
67N
67N SEF
67/ 46
68
78
50/27 SOTF/TOR
46BC
CTS
50BF-2
79-2
25-2
27/ 59
59N
FL
50BF
VTS
85
79
25
PSL
LEDs
conventional signalling
Inter MiCOM
protection communication
always available
optional
P443 & P446 only
P446 only
Distance Relays P443,P445 & P446
(Description of ANSI code nos. see protection Functions Overview)

Figure 1 - Functional diagram for P443 or P446 only

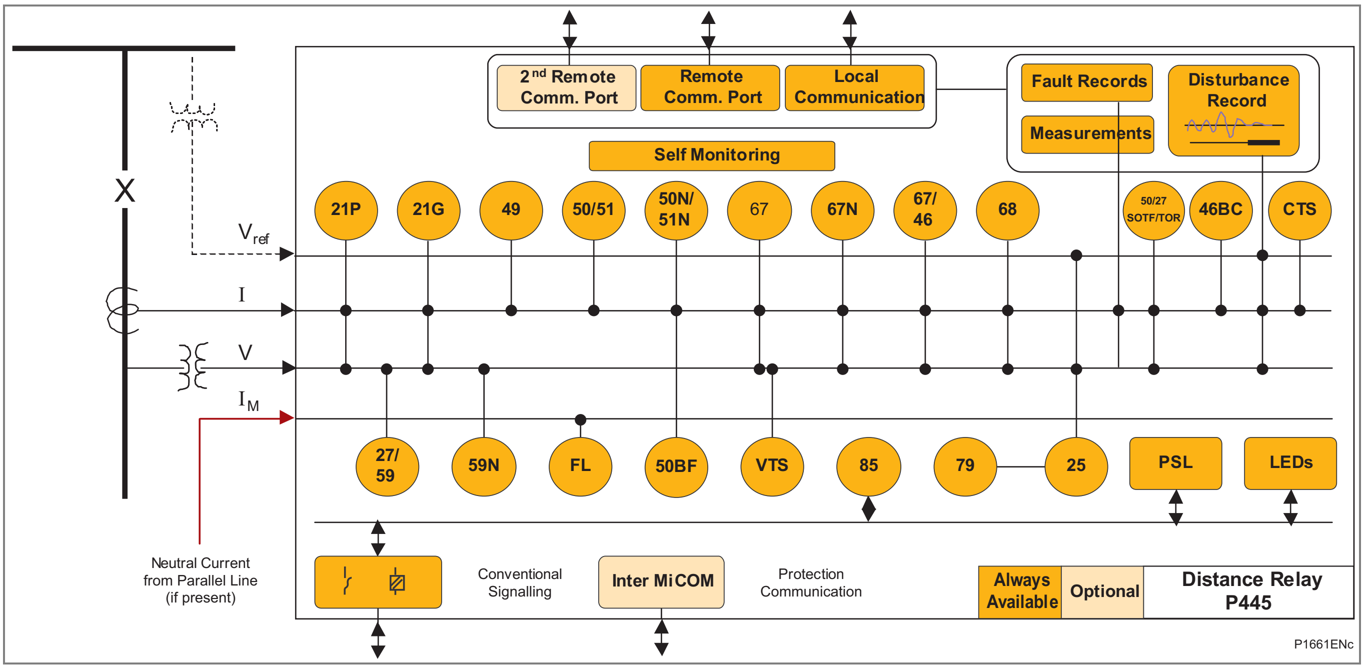
V_{ref}
I
V
I_M
Neutral Current from Parallel Line (if present)
2nd Remote Comm. Port
Remote Comm. Port
Local Communication
Fault Records
Disturbance Record
Measurements
Self Monitoring
21P
21G
49
50/51
50N/ 51N
67
67N
67/ 46
68
50/27 SOTF/TOR
46BC
CTS
27/ 59
59N
FL
50BF
VTS
85
79
25
PSL
LEDs
Conventional Signalling
Inter MiCOM
Protection Communication
Always Available
Optional
Distance Relay P445
P1661ENc

Figure 2 - Functional diagram for P445 only

4 ORDERING OPTIONS

For each product there are range of ordering options. The options vary from one product to another, and from one Software Version to another.

The information required with your order is given in the following sections:

- P443:
    - Ordering Options P443 for Software Version 55
    - Order Options for P443 for Software Version 57
    - Order Options for P443 for Software Version B0
    - Order Options for P443 for Software Version D0
- P445:
    - Ordering Options P445 for Software Version 35 & 36
    - Ordering Options P445 for Software Version 37
    - Order Options for P445 for Software Version E0
    - Order Options for P445 for Software Version F0
- P446:
    - Ordering Options P446 for Software Version 55
    - Ordering Options P446 for Software Version 57
    - Order Options for P446 for Software Version B0
    - Order Options for P446 for Software Version D0

4.1 Ordering Options P443 for Software Version 55

Distance Protection P443 1 & 3 pole tripping/re-closing Mho/Quad Distance with product options	Software Ver. 55
Nominal Auxiliary Voltage	
24 - 48V dc	1
48 - 110V dc (40 - 100V ac)	2
110 - 250V dc (100 - 240V ac)	3
In/Vn Rating	
Dual rated CT (1 & 5A: 100 - 120V)	1
Hardware Options	
Standard - none	1
IRIG-B only (Modulated)	2
Fiber optic converter only	3
IRIG-B (Modulated) & fiber optic converter	4
Ethernet (10Mbit/s) (Only on Suffix “G” or “J” Relays)	5
Ethernet (100Mbit/s)	6
Second rear comms + InterMiCOM	7
IRIG-B (Modulated) + second rear comms + InterMiCOM	8
Ethernet (100Mbit/s) plus IRIG-B (Modulated) (Only on “K” suffix relays)	A
Ethernet (100Mbit/s) plus IRIG-B (De-modulated) (Only on “K” suffix relays)	B
IRIG-B (De-modulated) (Only on “K” suffix relays)	C
Product Options	
16 inputs and 24 standard outputs	A
24 inputs and 32 standard outputs	B
16 inputs and 16 standard plus 4-high break outputs	C
24 inputs and 16 standard plus 8-high break outputs	D
As A with 850nm dual channel	E
As B with 850nm dual channel	F
As E + High Break	G
As F + High Break	H
As A + 1300nm SM single channel	J
As B + 1300nm SM single channel	K
As I + High Break	L
As J + High Break	M
As A + 1300nm SM dual channel	N
As B + 1300nm SM dual channel	O
As M + High Break	P
As N + High Break	Q
As A + 1300nm MM single channel	R
As B + 1300nm MM single channel	S
As Q + High Break	T
As R + High Break	U
As A + 1300nm MM dual channel	V
As B + 1300nm MM dual channel	W
As U + High Break	X
As V + High Break	Y
32 inputs and 32 outputs	Z
As B + 850nm MM + 1300mn SM	0
As D + 850nm MM + 1300mn SM	1

Distance Protection P443 1 & 3 pole tripping/re-closing Mho/Quad Distance with product options	Software Ver. 55
As B + 1300mn SM + 850nm MM	2
As D + 1300mn SM + 850nm MM	3
As B + 850nm MM + 1300mn MM	4
As D + 850nm MM + 1300mn MM	5
As B + 1300mn MM + 850nm MM	6
As D + 1300mn MM + 850nm MM	7
Protocol Options	
K-Bus	1
IEC870	3
DNP3.0	4
IEC61850 + Courier via rear RS485 port	6
IEC61850 + IEC60870-5-103 via rear RS485 port	7
DNP3.0 Over Ethernet	8
Mounting	
Flush/Panel Mounting	M
19” Rack Mounting	N
Language	
English, French, German, Spanish	0
English, French, German, Russian (only available on Design Suffix “K” devices)	5
English, French, Chinese	C
Software Version	
Date and application dependant	55
Setting file	
Default	0
Customer	1
Hardware Version	
Date and application dependent	K

4.2 Order Options for P443 for Software Version 57

Distance Protection P443 1 & 3 pole tripping/re-closing Mho/Quad Distance with product options	Software Ver. 57	
Nominal Auxiliary Voltage		
24 - 48 V dc		1
48 - 110 V dc (40 - 100 V ac)		2
110 - 250 V dc (100 - 240 V ac)		3
In/Vn Rating		
Dual rated CT (1 & 5 A: 100 - 120 V)		1
Hardware Options		
	Protocol Compatibility	
Standard - None	1, 3 & 4	1
IRIG-B Only (Modulated)	1, 3 & 4	2
Fiber Optic Converter Only	1, 3 & 4	3
IRIG-B (Modulated) & Fiber Optic Converter	1, 3 & 4	4
Ethernet (100 Mbit/s)	6, 7 & 8	6
Ethernet (100 Mbit/s) plus IRIG-B (Modulated)	6, 7 & 8	A
Ethernet (100 Mbit/s) plus IRIG-B (Un-modulated)	6, 7 & 8	B
IRIG-B (De-modulated)	1, 3 & 4	C
Second rear comms + Interrupt InterMiCOM	1, 3 & 4	E
IRIG-B (Modulated) + second rear comms + Interrupt InterMiCOM	1, 3 & 4	F
Redundant Ethernet Self-Healing Ring, 2 multi-mode fiber ports + Modulated IRIG-B	6, 7 & 8	G
Redundant Ethernet Self-Healing Ring, 2 multi-mode fiber ports + Un-modulated IRIG-B	6, 7 & 8	H
Redundant Ethernet RSTP, 2 multi-mode fiber ports + Modulated IRIG-B	6, 7 & 8	J
Redundant Ethernet RSTP, 2 multi-mode fiber ports + Un-modulated IRIG-B	6, 7 & 8	K
Redundant Ethernet Dual-Homing Star, 2 multi-mode fiber ports + Modulated IRIG-B	6, 7 & 8	L
Redundant Ethernet Dual-Homing Star, 2 multi-mode fiber ports + Un-modulated IRIG-B	6, 7 & 8	M
Product Options		
16 inputs and 24 standard outputs		A
24 inputs and 32 standard outputs		B
16 inputs and 16 standard plus 4-high break outputs		C
24 inputs and 16 standard plus 8-high break outputs		D
As A with 850nm dual channel		E
As B with 850 nm dual channel		F
As E + High Break		G
As F + High Break		H
As A + 1300 nm SM single channel		J
As B + 1300 nm SM single channel		K
As I + High Break		L
As J + High Break		M
As A + 1300 nm SM dual channel		N
As B + 1300 nm SM dual channel		O
As M + High Break		P
As N + High Break		Q
As A + 1300 nm MM single channel		R
As B + 1300 nm MM single channel		S
As Q + High Break		T
As R + High Break		U

Distance Protection P443 1 & 3 pole tripping/re-closing Mho/Quad Distance with product options	Software Ver. 57	
As A + 1300 nm MM dual channel		V
As B + 1300 nm MM dual channel		W
As U + High Break		X
As V + High Break		Y
32 inputs and 32 outputs		Z
As B + 850 nm MM + 1300 mn SM		0
As D + 850 nm MM + 1300 mn SM		1
As B + 1300 mn SM + 850 nm MM		2
As D + 1300 mn SM + 850 nm MM		3
As B + 850 nm MM + 1300 mn MM		4
As D + 850 nm MM + 1300 mn MM		5
As B + 1300 mn MM + 850 nm MM		6
As D + 1300 mn MM + 850 nm MM		7
Protocol Options		
	Hardware Compatibility	
K-Bus	1, 2, 3, 4, 7, 8 & C, E & F	1
IEC870	1, 2, 3, 4, 7, 8 & C, E & F	3
DNP3.0	1, 2, 3, 4, 7, 8 & C, E & F	4
IEC 61850 + Courier via rear RS485 port	6, A, B, G, H, J, K, L & M	6
IEC 61850+IEC 60870-5-103 via rear RS485 port	6, A, B, G, H, J, K, L & M	7
DNP3.0 Over Ethernet with Courier rear port K-Bus/RS485 protocol	6, A, B, G, H, J, K, L & M	8
Mounting		
Flush/Panel Mounting		M
19” Rack Mounting		N
Language		
English, French, German, Spanish		0
English, French, German, Russian (only available on Design Suffix “K” devices)		5
English, French, Chinese		C
Software Version		
Date and application dependant		57
Setting file		
Default		0
Customer		1
Hardware Version		
Date and application dependent		K

4.3 Order Options for P443 for Software Version B0

Distance Protection P443 1 & 3 pole tripping/re-closing MHO/Quad Distance with product options	Software Ver. B0	
Nominal Auxiliary Voltage		
24 - 48 V dc		1
48 - 110 V dc (40 - 100 V ac)		2
110 - 250 V dc (100 - 240 V ac)		3
In/Vn Rating		
Dual rated CT (1 & 5 A: 100 - 120 V)		1
Hardware Options		
	Protocol Compatibility	
Standard - None	1, 3 & 4	1
IRIG-B Only (Modulated)	1, 3 & 4	2
Fiber Optic Converter Only	1, 3 & 4	3
IRIG-B (Modulated) & Fiber Optic Converter	1, 3 & 4	4
Ethernet (100 Mbit/s)	6, 7 & 8	6
Ethernet (100Mbit/s) plus IRIG-B (Modulated) *	6, 7 & 8	A
Ethernet (100Mbit/s) plus IRIG-B (De-modulated) *	6, 7 & 8	B
InterMiCOM + Courier Rear Port ***	1, 3 & 4	E
InterMiCOM + Courier Rear Port + IRIG-B modulated ***	1, 3 & 4	F
Redundant Ethernet Self-Healing Ring, 2 multi-mode fibre ports + Modulated IRIG-B **	6, 7 & 8	G
Redundant Ethernet Self-Healing Ring, 2 multi-mode fibre ports + Un-modulated IRIG-B **	6, 7 & 8	H
Redundant Ethernet RSTP, 2 multi-mode fibre ports + Modulated IRIG-B **	6, 7 & 8	J
Redundant Ethernet RSTP, 2 multi-mode fibre ports + Un-modulated IRIG-B **	6, 7 & 8	K
Redundant Ethernet Dual-Homing Star, 2 multi-mode fibre ports + Modulated IRIG-B **	6, 7 & 8	L
Redundant Ethernet Dual-Homing Star, 2 multi-mode fibre ports + Un-modulated IRIG-B **	6, 7 & 8	M
* Only On "K" Suffix Relays)		
** Only on Suffix K relays with 55 Software & later		
*** Only on Suffix K relays with 57 Software, replaces hardware options '7' & '8'		
Product Options		
16 inputs and 24-standard outputs		A
24 inputs and 32-standard outputs		B
16 inputs and 16-standard plus 4-high break outputs		C
24 inputs and 16-standard plus 8-high break outputs		D
16 inputs and 24-standard outputs + 850nm dual channel		E
24 inputs and 32-standard outputs + 850nm dual channel		F
16 inputs and 16-standard plus 4-high break outputs + 850nm dual channel		G
24 inputs and 16-standard plus 8-high break outputs + 850nm dual channel		H
16 inputs and 24-standard outputs + 1300nm SM single channel		J
24 inputs and 32-standard outputs + 1300nm SM single channel		K
16 inputs and 16-standard plus 4-high break outputs + 1300nm SM single channel		L
24 inputs and 16-standard plus 8-high break outputs + 1300nm SM single channel		M
16 inputs and 24-standard outputs + 1300nm SM dual channel		N
24 inputs and 32-standard outputs + 1300nm SM dual channel		O
16 inputs and 16-standard plus 4-high break outputs + 1300nm SM dual channel		P
24 inputs and 16-standard plus 8-high break outputs + 1300nm SM dual channel		Q
16 inputs and 24-standard outputs + 1300nm MM single channel		R
24 inputs and 32-standard outputs + 1300nm MM single channel		S
16 inputs and 16-standard plus 4-high break outputs + 1300nm MM single channel		T

Distance Protection P443 1 & 3 pole tripping/re-closing MHO/Quad Distance with product options	Software Ver. B0										

24 inputs and 16-standard plus 8-high break outputs + 1300nm MM single channel	U
16 inputs and 24-standard outputs + 1300nm MM dual channel	V
24 inputs and 32-standard outputs + 1300nm MM dual channel	W
16 inputs and 16-standard plus 4-high break outputs + 1300nm MM dual channel	X
24 inputs and 16-standard plus 8-high break outputs + 1300nm MM dual channel	Y
32 inputs and 32-standard outputs (Only available on Design Suffix "K" devices with version "54" software and later)	Z
24 inputs and 32-standard outputs + 850nm MM + 1300nm SM dual channel	0
24 inputs and 16-standard plus 8-high break outputs + 850nm MM + 1300nm SM dual channel	1
24 inputs and 32-standard outputs + 1300nm SM + 850nm MM dual channel	2
24 inputs and 16-standard plus 8-high break outputs + 1300nm SM + 850nm MM dual channel	3
24 inputs and 32-standard outputs + 850nm MM + 1300nm MM dual channel	4
24 inputs and 16-standard plus 8-high break outputs + 850nm MM + 1300nm MM dual channel	5
24 inputs and 32-standard outputs + 1300nm MM + 850nm MM dual channel	6
24 inputs and 16-standard plus 8-high break outputs + 1300nm MM + 850nm MM dual channel	7

Protocol Options

	Hardware Compatibility	
K-Bus	1, 2, 3, 4, 7, 8 & C, E & F	1
IEC870	1, 2, 3, 4, 7, 8 & C, E & F	3
DNP3.0	1, 2, 3, 4, 7, 8 & C, E & F	4
IEC 61850 + Courier via rear RS485 port	6, A, B, G, H, J, K, L & M	6
IEC 61850+IEC 60870-5-103 via rear RS485 port	6, A, B, G, H, J, K, L & M	7
DNP3.0 Over Ethernet with Courier rear port K-Bus/RS485 protocol	6, A, B, G, H, J, K, L & M	8
* Available on Design Suffix "K" devices with version "54" software and later		

Mounting

Flush/Panel Mounting	M
19" Rack Mounting	N

Language

English, French, German, Spanish	0
English, French, German, Italian (not yet available)	4
Chinese, English or French via HMI, with English or French only via Communications port (With Suffix "K" & '52' and later software)	C

Software Version

Date and application dependant	B0

Customer specific options

Standard version	8
Customer version	9

Hardware Version

K = XCPU2	K

4.4 Order Options for P443 for Software Version D0

Distance Protection P443 1 & 3 pole tripping/re-closing MHO/Quad Distance with product options	Software Ver. D0	
Nominal Auxiliary Voltage		
24 - 48 V dc		1
48 - 110 V dc (40 - 100 V ac)		2
110 - 250 V dc (100 - 240 V ac)		3
In/Vn Rating		
Dual rated CT (1 & 5 A: 100 - 120 V)		1
Hardware Options		
	Protocol Compatibility	
Standard - None	1, 3 & 4	1
IRIG-B Only (Modulated)	1, 3 & 4	2
Fiber Optic Converter Only	1, 3 & 4	3
IRIG-B (Modulated) & Fiber Optic Converter	1, 3 & 4	4
Ethernet (100 Mbit/s)	6, 7 & 8	6
Ethernet (100Mbit/s) plus IRIG-B (Modulated) *	6, 7 & 8	A
Ethernet (100Mbit/s) plus IRIG-B (De-modulated) *	6, 7 & 8	B
InterMiCOM + Courier Rear Port ***	1, 3 & 4	E
InterMiCOM + Courier Rear Port + IRIG-B modulated ***	1, 3 & 4	F
Redundant Ethernet Self-Healing Ring, 2 multi-mode fibre ports + Modulated IRIG-B **	6, 7 & 8	G
Redundant Ethernet Self-Healing Ring, 2 multi-mode fibre ports + Un-modulated IRIG-B **	6, 7 & 8	H
Redundant Ethernet RSTP, 2 multi-mode fibre ports + Modulated IRIG-B **	6, 7 & 8	J
Redundant Ethernet RSTP, 2 multi-mode fibre ports + Un-modulated IRIG-B **	6, 7 & 8	K
Redundant Ethernet Dual-Homing Star, 2 multi-mode fibre ports + Modulated IRIG-B **	6, 7 & 8	L
Redundant Ethernet Dual-Homing Star, 2 multi-mode fibre ports + Un-modulated IRIG-B **	6, 7 & 8	M
* Only On "K" Suffix Relays)		
** Only on Suffix K relays with 55 Software & later		
*** Only on Suffix K relays with 57 Software, replaces hardware options '7' & '8'		
Product Options		
16 inputs and 24-standard outputs		A
24 inputs and 32-standard outputs		B
16 inputs and 16-standard plus 4-high break outputs		C
24 inputs and 16-standard plus 8-high break outputs		D
16 inputs and 24-standard outputs + 850nm dual channel		E
24 inputs and 32-standard outputs + 850nm dual channel		F
16 inputs and 16-standard plus 4-high break outputs + 850nm dual channel		G
24 inputs and 16-standard plus 8-high break outputs + 850nm dual channel		H
16 inputs and 24-standard outputs + 1300nm SM single channel		J
24 inputs and 32-standard outputs + 1300nm SM single channel		K
16 inputs and 16-standard plus 4-high break outputs + 1300nm SM single channel		L
24 inputs and 16-standard plus 8-high break outputs + 1300nm SM single channel		M
16 inputs and 24-standard outputs + 1300nm SM dual channel		N
24 inputs and 32-standard outputs + 1300nm SM dual channel		O
16 inputs and 16-standard plus 4-high break outputs + 1300nm SM dual channel		P
24 inputs and 16-standard plus 8-high break outputs + 1300nm SM dual channel		Q
16 inputs and 24-standard outputs + 1300nm MM single channel		R
24 inputs and 32-standard outputs + 1300nm MM single channel		S
16 inputs and 16-standard plus 4-high break outputs + 1300nm MM single channel		T

Distance Protection P443 1 & 3 pole tripping/re-closing MHO/Quad Distance with product options	Software Ver. D0										
24 inputs and 16-standard plus 8-high break outputs + 1300nm MM single channel					U						
16 inputs and 24-standard outputs + 1300nm MM dual channel					V						
24 inputs and 32-standard outputs + 1300nm MM dual channel					W						
16 inputs and 16-standard plus 4-high break outputs + 1300nm MM dual channel					X						
24 inputs and 16-standard plus 8-high break outputs + 1300nm MM dual channel					Y						
32 inputs and 32-standard outputs (Only available on Design Suffix "K" devices with version "54" software and later)					Z						
24 inputs and 32-standard outputs + 850nm MM + 1300nm SM dual channel					0						
24 inputs and 16-standard plus 8-high break outputs + 850nm MM + 1300nm SM dual channel					1						
24 inputs and 32-standard outputs + 1300nm SM + 850nm MM dual channel					2						
24 inputs and 16-standard plus 8-high break outputs + 1300nm SM + 850nm MM dual channel					3						
24 inputs and 32-standard outputs + 850nm MM + 1300nm MM dual channel					4						
24 inputs and 16-standard plus 8-high break outputs + 850nm MM + 1300nm MM dual channel					5						
24 inputs and 32-standard outputs + 1300nm MM + 850nm MM dual channel					6						
24 inputs and 16-standard plus 8-high break outputs + 1300nm MM + 850nm MM dual channel					7						

Protocol Options

	Hardware Compatibility	
K-Bus	1, 2, 3, 4, 7, 8 & C, E & F	1
IEC870	1, 2, 3, 4, 7, 8 & C, E & F	3
DNP3.0	1, 2, 3, 4, 7, 8 & C, E & F	4
IEC 61850 + Courier via rear RS485 port	6, A, B, G, H, J, K, L & M	6
IEC 61850+IEC 60870-5-103 via rear RS485 port	6, A, B, G, H, J, K, L & M	7
DNP3.0 Over Ethernet with Courier rear port K-Bus/RS485 protocol	6, A, B, G, H, J, K, L & M	8
* Available on Design Suffix "K" devices with version "54" software and later		

Mounting

Flush/Panel Mounting	M
19” Rack Mounting	N

Language

English, French, German, Spanish	0
English, French, German, Italian (not yet available)	4
Chinese, English or French via HMI, with English or French only via Communications port (With Suffix "K" & '52' and later software)	C

Software Version

Date and application dependant	D0

Customer specific options

Standard version	8
Customer version	9

Hardware Version

M = CPU3	M

4.5 Ordering Options P445 for Software Version 35 & 36

MiCOM P445 Distance protection 3 pole tripping/re-closing Mho/Quad Distance with product options	Software Ver. 35 & 36
Auxiliary Voltage Rating	
24 - 48 V dc only	1
48 - 110 V dc (40 - 110 V ac)	2
110 - 250 V dc (100 - 240 V ac)	3
In/Vn Rating	
Dual rated CT (1 & 5 A: 100 - 120 V ac)	1
Hardware Options	
Nothing	1
IRIG-B only	2
Fiber optic converter only (IEC 60870-5-103)	3
IRIG-B & fiber optic converter (IEC 60870-5-103)	4
Ethernet (100Mbit/s) *	6
Rear comms + EIA(RS)232 InterMiCOM	7
IRIG-B + Rear Comms + EIA(RS)232 InterMiCOM	8
Ethernet (100Mbit/s) plus IRIG-B (Modulated) *	A
Ethernet (100Mbit/s) plus IRIG-B (Un-modulated) *	B
IRIG-B (Un-modulated)	C
Product Specific	
Version with 8 inputs and 8 outputs (40TE)	A
Version with 12 inputs and 12 outputs (60TE)	B
Version with 16 inputs and 16 outputs (60TE)	C
Version with 16 inputs and 8 outputs and 4 high break (60TE)	D
As A with 820nm dual channel fiber interface	E
As B with 820nm dual channel fiber interface	F
As C with 820nm dual channel fiber interface	G
As D with 820nm dual channel fiber interface	H
As A with 1300nm single mode, single channel fiber interface	I
As B with 1300nm single mode, single channel fiber interface	J
As C with 1300nm single mode, single channel fiber interface	K
As D with 1300nm single mode, single channel fiber interface	L
As A with 1300nm single mode, dual channel fiber interface	M
As B with 1300nm single mode, dual channel fiber interface	N
As C with 1300nm single mode, dual channel fiber interface	O
As D with 1300nm single mode, dual channel fiber interface	P
As A with 1300nm multi mode, single channel fiber interface	Q
As B with 1300nm multi mode, single channel fiber interface	R
As C with 1300nm multi mode, single channel fiber interface	S
As D with 1300nm multi mode, single channel fiber interface	T
As A with 1300nm multi mode, dual channel fiber interface	U
As B with 1300nm multi mode, dual channel fiber interface	V
As C with 1300nm multi mode, dual channel fiber interface	W
As D with 1300nm multi mode, dual channel fiber interface	X
Note The above fiber interface options are used for InterMiCOM^{64} teleprotection.	
Protocol Options	
K-Bus/Courier	1
IEC 60870-5-103 (EIA(RS)485 or Fiber Optic)	3

MiCOM P445 Distance protection 3 pole tripping/re-closing Mho/Quad Distance with product options	Software Ver. 35 & 36										
DNP3.0						4					
IEC61850 + Courier via rear RS485 port **						6					
IEC61850 + IEC60870-5-103 via rear RS485 port **						7					
DNP3.0 Over Ethernet						8					
Mounting											
Flush/Panel Mounting							M				
Language											
Multilingual - English, French, German, Spanish								0			
Multilingual - English, French, German, Russian								5			
Multilingual - English, French, Chinese								C			
Software Version											
Unless specified the latest version will be delivered									35/36		
Settings File											
Default										0	
Hardware Suffix											
Original											J

4.6 Ordering Options P445 for Software Version 37

MiCOM P445 Distance protection 3 pole tripping/re-closing Mho/Quad Distance with product options	Software Ver. 37	
Auxiliary Voltage Rating		
24 - 48 V dc only		1
48 - 110 V dc (40 - 110 V ac)		2
110 - 250 V dc (100 - 240 V ac)		3
In/Vn Rating		
Dual rated CT (1 & 5 A: 100 - 120 V ac)		1
Hardware Options		
	Protocol Compatibility	
Standard - None	1, 3 & 4	1
IRIG-B only (Modulated)	1, 3 & 4	2
Fiber optic converter only	1, 3 & 4	3
IRIG-B (Modulated) & fiber optic converter	1, 3 & 4	4
Ethernet (100Mbit/s) *	6, 7 & 8	6
Ethernet (100Mbit/s) plus IRIG-B (Modulated) *	6, 7 & 8	A
Ethernet (100Mbit/s) plus IRIG-B (Un-modulated) *	6, 7 & 8	B
IRIG-B (Un-modulated)	1, 3 & 4	C
Second rear comms + Interrupt InterMiCOM 1, 3 & 4 E	1, 3 & 4	E
IRIG-B (Modulated) + second rear comms + Interrupt InterMiCOM	1, 3 & 4	F
Redundant Ethernet Self-Healing Ring, 2 multi-mode fiber ports + Modulated IRIG-B	6, 7 & 8	G
Redundant Ethernet Self-Healing Ring, 2 multi-mode fiber ports + Un-modulated IRIG-B	6, 7 & 8	H
Redundant Ethernet RSTP, 2 multi-mode fiber ports + Modulated IRIG-B	6, 7 & 8	J
Redundant Ethernet RSTP, 2 multi-mode fiber ports + Un-modulated IRIG-B	6, 7 & 8	K
Redundant Ethernet Dual-Homing Star, 2 multi-mode fiber ports + Modulated IRIG-B	6, 7 & 8	L
Redundant Ethernet Dual-Homing Star, 2 multi-mode fiber ports + Un-modulated IRIG-B	6, 7 & 8	M
Product Specific		
Version with 8 inputs and 8 outputs (40TE)		A
Version with 12 inputs and 12 outputs (60TE)		B
Version with 16 inputs and 16 outputs (60TE)		C
Version with 16 inputs and 8 outputs and 4 high break (60TE)		D
As A with 820nm dual channel fiber interface		E
As B with 820nm dual channel fiber interface		F
As C with 820nm dual channel fiber interface		G
As D with 820nm dual channel fiber interface		H
As A with 1300nm single mode, single channel fiber interface		I
As B with 1300nm single mode, single channel fiber interface		J
As C with 1300nm single mode, single channel fiber interface		K
As D with 1300nm single mode, single channel fiber interface		L
As A with 1300nm single mode, dual channel fiber interface		M
As B with 1300nm single mode, dual channel fiber interface		N
As C with 1300nm single mode, dual channel fiber interface		O
As D with 1300nm single mode, dual channel fiber interface		P
As A with 1300nm multi mode, single channel fiber interface		Q
As B with 1300nm multi mode, single channel fiber interface		R
As C with 1300nm multi mode, single channel fiber interface		S

MiCOM P445 Distance protection 3 pole tripping/re-closing Mho/Quad Distance with product options	Software Ver. 37	
As D with 1300nm multi mode, single channel fiber interface		T
As A with 1300nm multi mode, dual channel fiber interface		U
As B with 1300nm multi mode, dual channel fiber interface		V
As C with 1300nm multi mode, dual channel fiber interface		W
As D with 1300nm multi mode, dual channel fiber interface		X
Note The above fiber interface options are used for InterMiCOM^{64} teleprotection.		
Protocol Options		
	Hardware Compatibility	
K-Bus/Courier	1, 2, 3, 4, 7, 8 & C, E & F	1
IEC 60870-5-103 (EIA(RS)485 or Fiber Optic)	1, 2, 3, 4, 7, 8 & C, E & F	3
DNP3.0	1, 2, 3, 4, 7, 8 & C, E & F	4
IEC61850 + Courier via rear RS485 port **	6, A, B, G, H, J, K, L & M	6
IEC61850 + IEC60870-5-103 via rear RS485 port **	6, A, B, G, H, J, K, L & M	7
DNP3.0 Over Ethernet	6, A, B, G, H, J, K, L & M	8
Mounting		
Flush/Panel Mounting		M
Language		
Multilingual - English, French, German, Spanish		0
Multilingual - English, French, German, Russian		5
Multilingual - English, French, Chinese		C
Software Version		
Unless specified the latest version will be delivered		37
Settings File		
Default		0
Hardware Suffix		
Original		J

4.7 Order Options for P445 for Software Version E0

MiCOM P445 Distance protection 3 pole tripping/re-closing MHO/Quad Distance with product options	**Software Ver. E0**	
Auxiliary Voltage Rating		
24 - 48 V dc only		1
48 - 110 V dc (40 - 110 V ac)		2
110 - 250 V dc (100 - 240 V ac)		3
In/Vn Rating		
Dual rated CT (1 & 5 A: 100 - 120 V ac)		1
Hardware Options		
	Protocol Compatibility	
Standard Version	1, 3 & 4	1
IRIG-Input	1, 3 & 4	2
Fibre optic convertor (IEC60870-5-103)	1, 3 & 4	3
IRIG-B input and Fibre optic convertor (IEC60870-5-103)	1, 3 & 4	4
Ethernet (100Mbit/s) *	6, 7 & 8	6
Ethernet (100Mbit/s) plus IRIG-B (Modulated) *	6, 7 & 8	A
Ethernet (100Mbit/s) plus IRIG-B (De-modulated) *	6, 7 & 8	B
InterMiCOM + Courier Rear Port ***	1, 3 & 4	E
InterMiCOM + Courier Rear Port + IRIG-B modulated ***	1, 3 & 4	F
Redundant Ethernet Self-Healing Ring, 2 multi-mode fibre ports + Modulated IRIG-B **	6, 7 & 8	G
Redundant Ethernet Self-Healing Ring, 2 multi-mode fibre ports + Un-modulated IRIG-B **	6, 7 & 8	H
Redundant Ethernet RSTP, 2 multi-mode fibre ports + Modulated IRIG-B **	6, 7 & 8	J
Redundant Ethernet RSTP, 2 multi-mode fibre ports + Un-modulated IRIG-B **	6, 7 & 8	K
Redundant Ethernet Dual-Homing Star, 2 multi-mode fibre ports + Modulated IRIG-B **	6, 7 & 8	L
Redundant Ethernet Dual-Homing Star, 2 multi-mode fibre ports + Un-modulated IRIG-B **	6, 7 & 8	M
Product Specific		
3 Pole tripping/reclosing MHO/Quad Distance with 8 Inputs & 8 Outputs (40TE)		A
3 Pole tripping/reclosing MHO/Quad Distance with 12 Inputs & 12 Outputs (60TE)		B
3 Pole tripping/reclosing MHO/Quad Distance with 16 Inputs & 16 Outputs (60TE)		C
3 Pole tripping/reclosing MHO/Quad Distance with 16 Inputs, 8 Outputs & 4 High Break (60TE) *		D
As A with 820nm dual channel fiber interface		E
As B with 820nm dual channel fiber interface		F
As C with 820nm dual channel fiber interface		G
As D with 820nm dual channel fiber interface		H
As A with 1300nm single mode, single channel fiber interface		I
As B with 1300nm single mode, single channel fiber interface		J
As C with 1300nm single mode, single channel fiber interface		K
As D with 1300nm single mode, single channel fiber interface		L
As A with 1300nm single mode, dual channel fiber interface		M
As B with 1300nm single mode, dual channel fiber interface		N
As C with 1300nm single mode, dual channel fiber interface		O
As D with 1300nm single mode, dual channel fiber interface		P
As A with 1300nm multi mode, single channel fiber interface		Q
As B with 1300nm multi mode, single channel fiber interface		R

MiCOM P445 Distance protection 3 pole tripping/re-closing MHO/Quad Distance with product options	Software Ver. E0	
As C with 1300nm multi mode, single channel fiber interface		S
As D with 1300nm multi mode, single channel fiber interface		T
As A with 1300nm multi mode, dual channel fiber interface		U
As B with 1300nm multi mode, dual channel fiber interface		V
As C with 1300nm multi mode, dual channel fiber interface		W
As D with 1300nm multi mode, dual channel fiber interface		X
Protocol Options		
	Protocol Compatibility	
K-Bus	1, 2, 3, 4, C, E & F	1
VDEW (IEC 60870-5-103) (RS485 or Fibre Optic)	1, 2, 3, 4, C, E & F	3
DNP3.0	1, 2, 3, 4, C, E & F	4
IEC61850 + Courier via rear RS485 port **	6, A, B, G, H, J, K, L, M	6
IEC61850 + IEC60870-5-103 via rear RS485 port **	6, A, B, G, H, J, K, L, M	7
DNP3.0 Over Ethernet with Courier rear port K-Bus/RS485 protocol *	6, A, B, G, H, J, K, L, M	8
Mounting		
Flush/Panel Mounting		M
Language		
English, French, German, Spanish		0
English, French, German, Russian *		5
Chinese, English or French via HMI, with English or French only via Communications port *		C
Software Version		
Date and application dependant		E0
Customer specific options File		
Default		8
Customer		9
Hardware Suffix		
Model and hardware version dependant		J
* Software version '35' & later required ** Software version '36' required *** Only on relays with 37 Software, hardware options 'E' & 'F' replace options '7' & '8'		

4.8 Order Options for P445 for Software Version F0

MiCOM P445 Distance protection 3 pole tripping/re-closing MHO/Quad Distance with product options	Software Ver. F0	
Auxiliary Voltage Rating		
24 - 48 V dc only		1
48 - 110 V dc (40 - 110 V ac)		2
110 - 250 V dc (100 - 240 V ac)		3
In/Vn Rating		
Dual rated CT (1 & 5 A: 100 - 120 V ac)		1
Hardware Options		
	Protocol Compatibility	
Standard Version	1, 3 & 4	1
IRIG-Input	1, 3 & 4	2
Fibre optic convertor (IEC60870-5-103)	1, 3 & 4	3
IRIG-B input and Fibre optic convertor (IEC60870-5-103)	1, 3 & 4	4
Ethernet (100Mbit/s) *	6, 7 & 8	6
Ethernet (100Mbit/s) plus IRIG-B (Modulated) *	6, 7 & 8	A
Ethernet (100Mbit/s) plus IRIG-B (De-modulated) *	6, 7 & 8	B
InterMiCOM + Courier Rear Port ***	1, 3 & 4	E
InterMiCOM + Courier Rear Port + IRIG-B modulated ***	1, 3 & 4	F
Redundant Ethernet Self-Healing Ring, 2 multi-mode fibre ports + Modulated IRIG-B **	6, 7 & 8	G
Redundant Ethernet Self-Healing Ring, 2 multi-mode fibre ports + Un-modulated IRIG-B **	6, 7 & 8	H
Redundant Ethernet RSTP, 2 multi-mode fibre ports + Modulated IRIG-B **	6, 7 & 8	J
Redundant Ethernet RSTP, 2 multi-mode fibre ports + Un-modulated IRIG-B **	6, 7 & 8	K
Redundant Ethernet Dual-Homing Star, 2 multi-mode fibre ports + Modulated IRIG-B **	6, 7 & 8	L
Redundant Ethernet Dual-Homing Star, 2 multi-mode fibre ports + Un-modulated IRIG-B **	6, 7 & 8	M
Product Specific		
3 Pole tripping/reclosing MHO/Quad Distance with 8 Inputs & 8 Outputs (40TE)		A
3 Pole tripping/reclosing MHO/Quad Distance with 12 Inputs & 12 Outputs (60TE)		B
3 Pole tripping/reclosing MHO/Quad Distance with 16 Inputs & 16 Outputs (60TE)		C
3 Pole tripping/reclosing MHO/Quad Distance with 16 Inputs, 8 Outputs & 4 High Break (60TE) *		D
As A with 820nm dual channel fiber interface		E
As B with 820nm dual channel fiber interface		F
As C with 820nm dual channel fiber interface		G
As D with 820nm dual channel fiber interface		H
As A with 1300nm single mode, single channel fiber interface		I
As B with 1300nm single mode, single channel fiber interface		J
As C with 1300nm single mode, single channel fiber interface		K
As D with 1300nm single mode, single channel fiber interface		L
As A with 1300nm single mode, dual channel fiber interface		M
As B with 1300nm single mode, dual channel fiber interface		N
As C with 1300nm single mode, dual channel fiber interface		O
As D with 1300nm single mode, dual channel fiber interface		P
As A with 1300nm multi mode, single channel fiber interface		Q
As B with 1300nm multi mode, single channel fiber interface		R

MiCOM P445 Distance protection 3 pole tripping/re-closing MHO/Quad Distance with product options	Software Ver. F0	
As C with 1300nm multi mode, single channel fiber interface		S
As D with 1300nm multi mode, single channel fiber interface		T
As A with 1300nm multi mode, dual channel fiber interface		U
As B with 1300nm multi mode, dual channel fiber interface		V
As C with 1300nm multi mode, dual channel fiber interface		W
As D with 1300nm multi mode, dual channel fiber interface		X
Protocol Options		
	Protocol Compatibility	
K-Bus	1, 2, 3, 4, C, E & F	1
VDEW (IEC 60870-5-103) (RS485 or Fibre Optic)	1, 2, 3, 4, C, E & F	3
DNP3.0	1, 2, 3, 4, C, E & F	4
IEC61850 + Courier via rear RS485 port **	6, A, B, G, H, J, K, L, M	6
IEC61850 + IEC60870-5-103 via rear RS485 port **	6, A, B, G, H, J, K, L, M	7
DNP3.0 Over Ethernet with Courier rear port K-Bus/RS485 protocol *	6, A, B, G, H, J, K, L, M	8
Mounting		
Flush/Panel Mounting		M
Language		
English, French, German, Spanish		0
English, French, German, Russian *		5
Chinese, English or French via HMI, with English or French only via Communications port *		C
Software Version		
Date and application dependant		F0
Customer specific options File		
Default		8
Customer		9
Hardware Suffix		
Model and hardware version dependant		L

* Software version '35' & later required
** Software version '36' required
*** Only on relays with 37 Software, hardware options 'E' & 'F' replace options '7' & '8'

4.9 Ordering Options P446 for Software Version 55

Distance Protection P446 Distance & Auto-reclose for 2 circuit breakers	Software Ver. 55								**		
Nominal Auxiliary Voltage											
24 - 48V dc		1									
48 - 110V dc (40 - 100V ac)		2									
110 - 250V dc (100 - 240V ac)		3									
In/Vn Rating											
In = 1A/5A : Vn = 100 - 120 V ac			1								
Hardware Options											
	Protocol Compatibility										
Standard - None	1, 3 & 4			1							
IRIG-B Only (Modulated)	1, 3 & 4			2							
Fibre Optic Converter Only	1, 3 & 4			3							
IRIG-B (Modulated) & Fibre Optic Converter	1, 3 & 4			4							
Ethernet (100Mbit/s)	6, 7 & 8			6							
Second Rear Comms + InterMiCOM	1, 3 & 4			7							
IRIG-B (Modulated) + Second Rear Comms + InterMiCOM	1, 3 & 4			8							
Ethernet (100Mbit/s) plus IRIG-B (Modulated)	6, 7 & 8			A							
Ethernet (100Mbit/s) plus IRIG-B (De-modulated)	6, 7 & 8			B							
IRIG-B (De-modulated)	1, 3 & 4			C							
Product Options											
24 inputs and 32-standard outputs					B						
24 inputs and 8 standard plus 12 high break outputs					C						
24 inputs and 16 standard plus 8 high break outputs					D						
As B + 850nm dual channel					F						
As C + 850nm dual channel					G						
As D + 850nm dual channel					H						
As B + 1300nm SM single channel					J						
As C + 1300nm SM single channel					K						
As D + 1300nm SM single channel					L						
As B + 1300nm SM dual channel					N						
As C + 1300nm SM dual channel					O						
As D + 1300nm SM dual channel					P						
As B + 1300nm MM single channel					R						
As C + 1300nm MM single channel					S						
As D + 1300nm MM single channel					T						
As B + 1300nm MM dual channel					V						
As C + 1300nm MM dual channel					W						
As D + 1300nm MM dual channel					X						
As B + 850nm MM + 1300mn SM					Z						
As D + 850nm MM + 1300mn SM					1						
As B + 1300mn SM + 850nm MM					2						
As D + 1300mn SM + 850nm MM					3						
As B + 850nm MM + 1300mn MM					4						
As D + 850nm MM + 1300mn MM					5						

Distance Protection P446 Distance & Auto-reclose for 2 circuit breakers	Software Ver. 55	**
As B + 1300mn MM + 850nm MM		6
As D + 1300mn MM + 850nm MM		7
Protocol Options		
	Hardware Compatibility	
K-Bus	1, 2, 3, 4, 7, 8 & C	1
IEC870	1, 2, 3, 4, 7, 8 & C	3
DNP3.0	1, 2, 3, 4, 7, 8 & C	4
IEC61850 + Courier via rear RS485 port	6, A & B	6
IEC61850+IEC60870-5-103 via rear RS485 port	6, A & B	7
DNP3.0 Over Ethernet with Courier rear port K-Bus/RS485 protocol	6, A & B	8
Mounting		
Flush/Panel Mounting		M
19" Rack Mounting		N
Language		
English, French, German, Spanish		0
English, French, German, Russian		5
Chinese, English or French via HMI, with English or French only via Communications port		C
Software Version		
Date and application dependant		55
Customer Specific Options		
Standard version		0
Customer version		A
Hardware Version		
K = XCPU2		K

4.10 Ordering Options P446 for Software Version 57

Distance Protection P446 Distance & Auto-reclose for 2 circuit breakers	Software Ver. 57								**		
Nominal Auxiliary Voltage											
24 - 48 V dc		1									
48 - 110 V dc (40 - 100 V ac)		2									
110 - 250 V dc (100 - 240 V ac)		3									
In/Vn Rating											
In = 1A/5A : Vn = 100 - 120 V ac			1								
Hardware Options											
	Protocol Compatibility										
Standard - None	1, 3 & 4			1							
IRIG-B Only (Modulated)	1, 3 & 4			2							
Fibre Optic Converter Only	1, 3 & 4			3							
IRIG-B (Modulated) & Fiber Optic Converter	1, 3 & 4			4							
Ethernet (100 Mbit/s)	6, 7 & 8			6							
Ethernet (100 Mbit/s) plus IRIG-B (Modulated)	6, 7 & 8			A							
Ethernet (100 Mbit/s) plus IRIG-B (De-modulated)	6, 7 & 8			B							
IRIG-B (De-modulated)	1, 3 & 4			C							
Second rear comms + Interrupt InterMiCOM	1, 3 & 4			E							
IRIG-B (Modulated) + second rear comms + Interrupt InterMiCOM	1, 3 & 4			F							
Redundant Ethernet Self-Healing Ring, 2 multi-mode fiber ports + Modulated IRIG-B	6, 7 & 8			G							
Redundant Ethernet Self-Healing Ring, 2 multi-mode fiber ports + Un-modulated IRIG-B	6, 7 & 8			H							
Redundant Ethernet RSTP, 2 multi-mode fiber ports + Modulated IRIG-B	6, 7 & 8			J							
Redundant Ethernet RSTP, 2 multi-mode fiber ports + Un-modulated IRIG-B	6, 7 & 8			K							
Redundant Ethernet Dual-Homing Star, 2 multi-mode fiber ports + Modulated IRIG-B	6, 7 & 8			L							
Redundant Ethernet Dual-Homing Star, 2 multi-mode fiber ports + Un-modulated IRIG-B	6, 7 & 8			M							
Product Options											
24 inputs and 32-standard outputs					B						
24 inputs and 8 standard plus 12 high break outputs					C						
24 inputs and 16 standard plus 8 high break outputs					D						
As B + 850 nm dual channel					F						
As C + 850 nm dual channel					G						
As D + 850 nm dual channel					H						
As B + 1300 nm SM single channel					J						
As C + 1300 nm SM single channel					K						
As D + 1300 nm SM single channel					L						
As B + 1300 nm SM dual channel					N						
As C + 1300 nm SM dual channel					O						
As D + 1300 nm SM dual channel					P						
As B + 1300 nm MM single channel					R						
As C + 1300 nm MM single channel					S						
As D + 1300 nm MM single channel					T						
As B + 1300 nm MM dual channel					V						
As C + 1300 nm MM dual channel					W						

Distance Protection P446 Distance & Auto-reclose for 2 circuit breakers	Software Ver. 57	**
As D + 1300 nm MM dual channel		X
As B + 850 nm MM + 1300 mn SM		Z
As D + 850 nm MM + 1300 mn SM		1
As B + 1300 mn SM + 850 nm MM		2
As D + 1300 mn SM + 850 nm MM		3
As B + 850 nm MM + 1300 mn MM		4
As D + 850 nm MM + 1300 mn MM		5
As B + 1300 mn MM + 850 nm MM		6
As D + 1300 mn MM + 850 nm MM		7
Protocol Options		
	Hardware Compatibility	
K-Bus	1, 2, 3, 4, 7, 8 & C, E & F	1
IEC870	1, 2, 3, 4, 7, 8 & C, E & F	3
DNP3.0	1, 2, 3, 4, 7, 8 & C, E & F	4
IEC 61850 + Courier via rear RS485 port	6, A, B, G, H, J, K, L & M	6
IEC 61850+IEC 60870-5-103 via rear RS485 port	6, A, B, G, H, J, K, L & M	7
DNP3.0 Over Ethernet with Courier rear port K-Bus/RS485 protocol	6, A, B, G, H, J, K, L & M	8
Mounting		
Flush/Panel Mounting		M
19" Rack Mounting		N
Language		
English, French, German, Spanish		0
English, French, German, Russian		5
Chinese, English or French via HMI, with English or French only via Communications port		C
Software Version		
Date and application dependant		57
Customer Specific Options		
Standard version		0
Customer version		A
Hardware Version		
K = XCPU2		K

4.11 Order Options for P446 for Software Version B0

Distance Protection P446 Distance & Auto-reclose for 2 circuit breakers	Software Ver. B0								**		

Nominal Auxiliary Voltage	
24 - 48 V dc	1
48 - 110 V dc (40 - 100 V ac)	2
110 - 250 V dc (100 - 240 V ac)	3

In/Vn Rating	
In = 1A/5A : Vn = 100 - 120 V ac	1

Hardware Options	Protocol Compatibility	
Nothing	1, 3 & 4	1
IRIG-B Only (Modulated)	1, 3 & 4	2
Fibre Optic Converter Only	1, 3 & 4	3
IRIG-B (Modulated) & Fiber Optic Converter	1, 3 & 4	4
Ethernet (100 Mbit/s)	6, 7 & 8	6
Second Rear Comms + InterMiCOM	1, 3 & 4	7
IRIG-B (Modulated) + Second Rear Comms + InterMiCOM	1, 3 & 4	8
InterMiCOM + Courier Rear Port	1, 3 & 4	E
InterMiCOM + Courier Rear Port + IRIG-B modulated	1, 3 & 4	F
Redundant Ethernet Self-Healing Ring, 2 multi-mode fibre ports + Modulated IRIG-B	6, 7 & 8	G
Redundant Ethernet Self-Healing Ring, 2 multi-mode fibre ports + Un-modulated IRIG-B	6, 7 & 8	H
Redundant Ethernet RSTP, 2 multi-mode fibre ports + Modulated IRIG-B	6, 7 & 8	J
Redundant Ethernet RSTP, 2 multi-mode fibre ports + Un-modulated IRIG-B	6, 7 & 8	K
Redundant Ethernet Dual-Homing Star, 2 multi-mode fibre ports + Modulated IRIG-B	6, 7 & 8	L
Redundant Ethernet Dual-Homing Star, 2 multi-mode fibre ports + Un-modulated IRIG-B	6, 7 & 8	M

Product Options	
24 inputs and 32-standard outputs	B
24 inputs and 8 standard plus 12 high break outputs	C
24 inputs and 16 standard plus 8 high break outputs	D
As B + 850 nm dual channel	F
As C + 850 nm dual channel	G
As D + 850 nm dual channel	H
As B + 1300 nm SM single channel	J
As C + 1300 nm SM single channel	K
As D + 1300 nm SM single channel	L
As B + 1300 nm SM dual channel	N
As C + 1300 nm SM dual channel	O
As D + 1300 nm SM dual channel	P
As B + 1300 nm MM single channel	R
As C + 1300 nm MM single channel	S
As D + 1300 nm MM single channel	T
As B + 1300 nm MM dual channel	V

Distance Protection P446 Distance & Auto-reclose for 2 circuit breakers	Software Ver. B0	**
As C + 1300 nm MM dual channel		W
As D + 1300 nm MM dual channel		X
As B + 850 nm MM + 1300 mn SM		Z
As D + 850 nm MM + 1300 mn SM		1
As B + 1300 mn SM + 850 nm MM		2
As D + 1300 mn SM + 850 nm MM		3
As B + 850 nm MM + 1300 mn MM		4
As D + 850 nm MM + 1300 mn MM		5
As B + 1300 mn MM + 850 nm MM		6
As D + 1300 mn MM + 850 nm MM		7
Protocol Options		
	Hardware Compatibility	
K-Bus	1, 2, 3, 4, 7, 8 & C, E & F	1
IEC870	1, 2, 3, 4, 7, 8 & C, E & F	3
DNP3.0	1, 2, 3, 4, 7, 8 & C, E & F	4
IEC 61850 + Courier via rear RS485 port	6, A, B, G, H, J, K, L & M	6
IEC 61850+IEC 60870-5-103 via rear RS485 port	6, A, B, G, H, J, K, L & M	7
DNP3.0 Over Ethernet with Courier rear port K-Bus/RS485 protocol	6, A, B, G, H, J, K, L & M	8
Mounting		
Flush/Panel Mounting		M
19" Rack Mounting		N
Language		
English, French, German, Spanish		0
English, French, German, Italian (Not yet available)		4
English, French, German, Russian		5
Chinese, English or French via HMI, with English or French only via Communications port		C
Software Version		
Date and application dependant		B0
Customer Specific Options		
Standard version		0
Customer version		A
Hardware Version		
K = XCPU2		K

4.12 Order Options for P446 for Software Version D0

Distance Protection P446 Distance & Auto-reclose for 2 circuit breakers	Software Ver. D0								**		

Nominal Auxiliary Voltage		
24 - 48 V dc		1
48 - 110 V dc (40 - 100 V ac)		2
110 - 250 V dc (100 - 240 V ac)		3
In/Vn Rating		
In = 1A/5A : Vn = 100 - 120 V ac		1
Hardware Options		
	Protocol Compatibility	
Nothing	1, 3 & 4	1
IRIG-B Only (Modulated)	1, 3 & 4	2
Fibre Optic Converter Only	1, 3 & 4	3
IRIG-B (Modulated) & Fiber Optic Converter	1, 3 & 4	4
Ethernet (100 Mbit/s)	6, 7 & 8	6
Second Rear Comms + InterMiCOM	1, 3 & 4	7
IRIG-B (Modulated) + Second Rear Comms + InterMiCOM	1, 3 & 4	8
InterMiCOM + Courier Rear Port	1, 3 & 4	E
InterMiCOM + Courier Rear Port + IRIG-B modulated	1, 3 & 4	F
Redundant Ethernet Self-Healing Ring, 2 multi-mode fibre ports + Modulated IRIG-B	6, 7 & 8	G
Redundant Ethernet Self-Healing Ring, 2 multi-mode fibre ports + Un-modulated IRIG-B	6, 7 & 8	H
Redundant Ethernet RSTP, 2 multi-mode fibre ports + Modulated IRIG-B	6, 7 & 8	J
Redundant Ethernet RSTP, 2 multi-mode fibre ports + Un-modulated IRIG-B	6, 7 & 8	K
Redundant Ethernet Dual-Homing Star, 2 multi-mode fibre ports + Modulated IRIG-B	6, 7 & 8	L
Redundant Ethernet Dual-Homing Star, 2 multi-mode fibre ports + Un-modulated IRIG-B	6, 7 & 8	M
Product Options		
24 inputs and 32-standard outputs		B
24 inputs and 8 standard plus 12 high break outputs		C
24 inputs and 16 standard plus 8 high break outputs		D
As B + 850 nm dual channel		F
As C + 850 nm dual channel		G
As D + 850 nm dual channel		H
As B + 1300 nm SM single channel		J
As C + 1300 nm SM single channel		K
As D + 1300 nm SM single channel		L
As B + 1300 nm SM dual channel		N
As C + 1300 nm SM dual channel		O
As D + 1300 nm SM dual channel		P
As B + 1300 nm MM single channel		R
As C + 1300 nm MM single channel		S
As D + 1300 nm MM single channel		T
As B + 1300 nm MM dual channel		V

Distance Protection P446 Distance & Auto-reclose for 2 circuit breakers	Software Ver. D0								**		
As C + 1300 nm MM dual channel					W						
As D + 1300 nm MM dual channel					X						
As B + 850 nm MM + 1300 mn SM					Z						
As D + 850 nm MM + 1300 mn SM					1						
As B + 1300 mn SM + 850 nm MM					2						
As D + 1300 mn SM + 850 nm MM					3						
As B + 850 nm MM + 1300 mn MM					4						
As D + 850 nm MM + 1300 mn MM					5						
As B + 1300 mn MM + 850 nm MM					6						
As D + 1300 mn MM + 850 nm MM					7						
Protocol Options											
	Hardware Compatibility										
K-Bus	1, 2, 3, 4, 7, 8 & C, E & F					1					
IEC870	1, 2, 3, 4, 7, 8 & C, E & F					3					
DNP3.0	1, 2, 3, 4, 7, 8 & C, E & F					4					
IEC 61850 + Courier via rear RS485 port	6, A, B, G, H, J, K, L & M					6					
IEC 61850+IEC 60870-5-103 via rear RS485 port	6, A, B, G, H, J, K, L & M					7					
DNP3.0 Over Ethernet with Courier rear port K-Bus/RS485 protocol	6, A, B, G, H, J, K, L & M					8					
Mounting											
Flush/Panel Mounting							M				
19" Rack Mounting							N				
Language											
English, French, German, Spanish								0			
English, French, German, Italian (Not yet available)								4			
English, French, German, Russian								5			
Chinese, English or French via HMI, with English or French only via Communications port								C			
Software Version											
Date and application dependant									D0		
Customer Specific Options											
Standard version										0	
Customer version										A	
Hardware Version											
M = XCPU2											M

TECHNICAL DATA

CHAPTER 2

Date:	02/2013
Hardware Suffix:	K
Software Version:	57/B0
Connection Diagrams:	10P44303 (SH 01 and 03) 10P44304 (SH 01 and 03) 10P44305 (SH 01 and 03) 10P44306 (SH 01 and 03) 10P44600 10P44601 (SH 1 to 2) 10P44602 (SH 1 to 2) 10P44603 (SH 1 to 2)

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MECHANICAL SPECIFICATIONS

Design

Modular MiCOM Px40 platform relay, 80TE, front of panel flush mounting, or 19” rack mounted (ordering options).

Enclosure Protection

Per IEC 60529: 1989
IP 52 Protection (front panel) against dust and dripping water.
IP 30 Protection for sides of the case.
IP 10 Protection for the rear.

Weight

Approx. 11 kg

TERMINALS

AC Current and Voltage Measuring Inputs

Located on heavy duty (black) terminal block:
Threaded M4 terminals, for ring lug connection.
CT inputs have integral safety shorting, upon removal of the terminal block.

General Input/Output Terminals

For power supply, opto inputs, output contacts and COM1 rear communications.
Located on general purpose (grey) blocks:
Threaded M4 terminals, for ring lug connection.

Case Protective Earth Connection

Two rear stud connections, threaded M4.
Must be earthed (grounded) for safety, minimum earth wire size 2.5mm2.

Front Port Serial PC Interface

EIA(RS)232 DTE, 9 pin D-type female connector.
Courier protocol for interface to MiCOM S1 Studio software.
Isolation to ELV level.
Maximum cable length 15m.

Front Download/Monitor Port

EIA(RS)232, 25 pin D-type female connector.
For firmware downloads.
Isolation to ELV level.

Rear Communications Port

EIA(RS)485 signal levels, two wire connections located on general purpose block, M4 screw.
For screened twisted pair cable, multi-drop, 1000m max.
For K-Bus, IEC-870-5-103, or DNP3.0 protocol (ordering options).
Isolation to SELV level.

Optional Second Rear Communications port

EIA(RS)232, 9 pin D-type female connector, socket SK4.
Courier protocol: K-Bus, EIA(RS)232, or EIA(RS)485 connection.
Isolation to SELV level.

Optional Rear IRIG-B Interface Modulated or Unmodulated

BNC socket
Isolation to SELV level.
50 ohm coaxial cable.

Optional Rear Fiber Connection for SCADA/DCS

BFOC 2.5 -(ST®)-interface for glass fiber, as per IEC 874-10.
850nm short-haul fibers, one Tx and one Rx. For Courier, IEC-870-5-103 or DNP3.0 protocol (ordering options).

Optional rear Ethernet Connection for IEC 61850 or DNP3

10BaseT/100BaseTX communications

Interface in accordance with IEEE802.3 and IEC 61850

Isolation:	1.5kV
Connector type:	RJ45
Cable type:	Screened Twisted Pair (STP)
Max. cable length:	100m

100 Base FX interface

Interface in accordance with IEEE802.3 and IEC 61850

Wavelength:	1300nm
Fiber:	Multi-mode 50/125µm or 62.5/125µm
Connector type:	BFOC 2.5 -(ST®)

RATINGS

AC measuring inputs

Nominal frequency: 50 and 60 Hz (settable)
Operating range: 45 to 65Hz
Phase rotation: ABC or CBA

AC current

Nominal current (In): 1 and 5 A dual rated.
(1A and 5A inputs use different transformer tap connections, check correct terminals are wired).
Nominal burden per phase: < 0.15 VA at In
Thermal withstand:
continuous 4 In for 10s: 30 In
for 1s; 100 In
Linear to 64 In (non-offset AC current).

AC voltage

Nominal voltage (Vn): 100 to 120 V phase-phase..
Nominal burden per phase: < 0.02 VA at Vn.
Thermal withstand: continuous 2 Vn
for 10s: 2.6 Vn

POWER SUPPLY

Auxiliary voltage (Vx)

Three ordering options:
(i) Vx: 24 to 48 Vdc
(ii) Vx: 48 to 110 Vdc, and
40 to 100Vac (rms)
(iii) Vx: 110 to 250 Vdc, and
100 to 240Vac (rms)

Operating range

(i) 19 to 65V (dc only for this variant)
(ii) 37 to 150V (dc), 32 to 110V (ac)
(iii) 87 to 300V (dc), 80 to 265V (ac)
With a tolerable ac ripple of up to 12% for a dc supply, per IEC 60255-11: 1979.

Nominal burden

Quiescent burden: 11W. (Extra 1.25W when fitted with second rear communications board)
Additions for energized binary inputs/outputs:
Per opto input:
0.09W (24 to 54V),
0.12W (110/125V),
0.19W (220/120V).
Per energized output relay: 0.13W

Power-up Time

Time to power up < 11s.

Power Supply Interruption

Per IEC 60255-11: 1979
The relay will withstand a 20ms interruption in the DC auxiliary supply, without de-energizing.
Per IEC 61000-4-11: 1994
The relay will withstand a 20ms interruption in an AC auxiliary supply, without de-energizing.

Battery Backup

Front panel mounted
Type ½ AA, 3.6V Lithium Thionyl Chloride Battery

Field Voltage Output

Regulated 48Vdc
Current limited at 112mA maximum output
Digital (opto) inputs
Universal opto inputs with programmable voltage thresholds. May be energized from the 48V field voltage, or the external battery supply.
Rated nominal voltage: 24 to 250Vdc
Operating range: 19 to 265Vdc
Withstand: 300Vdc.
Nominal pick-up and reset thresholds:
Nominal Battery 24/27: 60 - 80% DO/PU
(logic 0) <16.2 (logic 1) >19.2
Nominal Battery 24/27: 50 - 70% DO/PU
(logic 0) <12.0 (logic 1) >16.8
Nominal Battery 30/34: 60 - 80% DO/PU
(logic 0) <20.4 (logic 1) >24.0
Nominal Battery 30/34: 50 - 70% DO/PU
(logic 0) <15.0 (logic 1) >21.0
Nominal Battery 48/54: 60 - 80% DO/PU
(logic 0) <32.4 (logic 1) >38.4
Nominal Battery 48/54: 50 - 70% DO/PU
(logic 0) <24.0 (logic 1) >33.6
Nominal Battery 110/125: 60 - 80% DO/PU
(logic 0) <75.0 (logic 1) >88.0
Nominal Battery 110/125: 50 - 70% DO/PU
(logic 0) <55.0 (logic 1) >77.0
Nominal Battery 220/250: 60 - 80% DO/PU
(logic 0) <150.0 (logic 1) >176.0
Nominal Battery 220/250: 50 - 70% DO/PU
(logic 0) <110 (logic 1) >154
Recognition time:
<2ms with long filter removed,
<12ms with half-cycle ac immunity filter on.

OUTPUT CONTACTS

Standard Contacts

General purpose relay outputs for signaling, tripping and alarming:

Continuous Carry Ratings (Not Switched):
Maximum continuous current: 10A (UL: 8A)
Short duration withstand carry: 30A for 3s
250A for 30ms
Rated voltage: 300 V

Make & Break Capacity:

DC: 50W resistive
DC: 62.5W inductive (L/R = 50ms)
AC: 2500VA resistive (cos ϕ = unity)
AC: 2500VA inductive (cos ϕ = 0.7)

Make, Carry:

30A for 3 secs. dc resistive, 10,000 operations (subject to the above limits of make/break capacity and rated voltage)

Make, Carry & Break:

30A for 200ms, ac resistive, 2,000 operations (subject to the above limits of make/break capacity & rated voltage)
4A for 1.5 secs. dc resistive, 10,000 operations (subject to the above limits of make/break capacity & rated voltage)

0.5A for 1 sec. dc inductive, 10,000 operations (subject to the above limits of make/break capacity & rated voltage)
10A for 1.5 secs. ac resistive/inductive, 10,000 operations (subject to the above limits of make/break capacity & rated voltage)

Durability:

Loaded contact: 10 000 operations minimum
Unloaded contact: 100 000 operations minimum
Operate Time: Less than 5ms
Reset Time: Less than 5ms

High Break Contacts (Option)

Continuous Carry Ratings (Not Switched):
Maximum continuous current: 10A
Short duration withstand carry: 30A for 3s
250A for 30ms
Rated voltage: 300 V

Make & Break Capacity:

DC: 7500W resistive
DC: 2500W inductive (L/R = 50ms)

Make, Carry:

30A for 3 secs. dc resistive, 10,000 operations (subject to the above limits of make/break capacity & rated voltage)

Make, Carry & Break:

30A for 3 secs. dc resistive, 5,000 operations (subject to the above limits of make/break capacity & rated voltage)
30A for 200 ms, dc resistive, 10,000 operations (subject to the above limits of make/break capacity & rated voltage)
10A (*), dc inductive, 10,000 operations (subject to the above limits of make/break capacity & rated voltage)

*Typical for repetitive shots - 2 minutes idle for thermal dissipation

Voltage	Current	L/R	No. of Shots in 1 sec
65V	10A	40ms	5
150V	10A	40ms	4
250V	10A	40ms	2
250V	10A	20ms	4
MOV protection: Max Voltage 330V dc			

Durability:

Loaded contact: 10 000 operations minimum
Unloaded contact: 100 000 operations minimum
Operate Time: Less than 0.2ms
Reset Time: Less than 8ms

Watchdog Contacts

Non-programmable contacts for relay healthy/relay fail indication:

Breaking capacity:
DC: 30W resistive
DC: 15W inductive (L/R = 40ms)
AC: 375VA inductive (cos ϕ = 0.7)

IRIG-B 12X interface (modulated)

External clock synchronization per IRIG standard 200-98, format B12X.
Input impedance 6kΩ at 1000Hz
Modulation ratio: 3:1 to 6:1
Input signal, peak-peak: 200mV to 20V

IRIG-B 00X interface (unmodulated)

External clock synchronization per IRIG standard 200-98, format B00X.
Input signal TTL level
Input impedance at dc 10kΩ

ENVIRONMENTAL CONDITIONS

Ambient Temperature Range

Per IEC 60255-6: 1988
Operating temperature range:
-25°C to +55°C (or -13°F to +131°F).
Storage and transit:
-25°C to +70°C (or -13°F to +158°F).

Ambient Humidity Range

Per IEC 60068-2-3: 1969:
56 days at 93% relative humidity and +40°C
Per IEC 60068-2-30: 1980:
Damp heat cyclic, six (12 + 12) hour cycles, 93% RH, +25 to +55°C.

Corrosive Environments

Per IEC 60068-2-60: 1995, Part 2, Test Ke, Method (class) 3
Industrial corrosive environment/poor environmental control, mixed gas flow test.
21 days at 75% relative humidity and +30°C exposure to elevated concentrations of H2S, NO2, Cl2 and SO2.

TYPE TESTS

Insulation
Per IEC 60255-27: 2005,
Insulation resistance > 100MΩ at 500Vdc
(Using only electronic/brushless insulation tester).
Creepage distances and clearances
Per EN 60255-27: 2005
Pollution degree 3,
Overvoltage category III,
Impulse test voltage 5 kV.
High voltage (dielectric) withstand
EIA(RS)232 ports excepted.

(i) Per IEC 60255-27: 2005, 2 kV rms AC, 1 minute:
Between all case terminals connected together, and the case earth.
Also, between all terminals of independent circuits.
1kV rms AC for 1 minute, across open watchdog contacts.
1kV rms AC for 1 minute, across open contacts of changeover output relays.

(ii) Per ANSI/IEEE C37.90-1989 (reaffirmed 1994):
1.5 kV rms AC for 1 minute, across open contacts of changeover output relays.
Impulse voltage withstand test
Per IEC 60255-27: 2005
Front time: 1.2 µs, time to half-value: 50 µs,
Peak value: 5 kV, 0.5J
Between all terminals, and all terminals and case earth.

ELECTROMAGNETIC COMPATIBILITY (EMC)

1 MHz Burst High Frequency Disturbance Test

Per IEC 60255-22-1: 1988, Class III,
Common-mode test voltage: 2.5 kV,
Differential test voltage: 1.0 kV,
Test duration: 2s, Source impedance: 200Ω
EIA(RS)232 ports excepted

100kHz Damped Oscillatory Test

Per EN61000-4-18: 2006 Level 3
2.5kV peak between independent circuits and case earth.
1.0kV peak across terminal of the same circuit.
Immunity to electrostatic discharge
Per IEC 60255-22-2: 1996, Class 4,
15kV discharge in air to user interface, display, and exposed metalwork.
Per IEC 60255-22-2: 1996, Class 3,
8kV discharge in air to all communication ports.
6kV point contact discharge to any part of the front of the product.

Electrical Fast Transient Or Burst Requirements

Per IEC 60255-22-4: 2002. Test severity Class III and IV:
Amplitude: 2 kV, burst frequency 5kHz (Class III),
Amplitude: 4 kV, burst frequency 2.5kHz (Class IV).
Applied directly to auxiliary supply, and applied to all other inputs. EIA(RS)232 ports excepted.

Surge Withstand Capability

IEEE/ANSI C37.90.1: 2002:
4kV fast transient and 2.5kV oscillatory applied common mode and differential mode to opto inputs (filtered), output relays, CTs, VTs, power supply, field voltage.
4kV fast transient and 2.5kV oscillatory applied common mode to communications, IRIG-B.

Surge Immunity Test

EIA(RS)232 ports excepted.
Per IEC 61000-4-5: 2002 Level 4,
Time to half-value: 1.2/50 µs,
Amplitude: 4kV between all groups and case earth,
Amplitude: 2kV between terminals of each group.

Immunity to Radiated Electromagnetic Energy

Per IEC 60255-22-3: 2000, Class III:

Test field strength, frequency band 80 to 1000 MHz:

10 V/m,

Test using AM: 1 kHz / 80%,

Spot tests at 80, 160, 450, 900 MHz

Per IEEE/ANSI C37.90.2: 1995:

25MHz to 1000MHz, zero and 100% square wave modulated.

Field strength of 35V/m.

Radiated Immunity from Digital Communications

Per EN61000-4-3: 2002, Level 4:

Test field strength, frequency band 800 to 960 MHz, and 1.4 to 2.0 GHz: 30 V/m,

Test using AM: 1 kHz / 80%.

Radiated Immunity from Digital Radio Telephones

Per ENV 50204: 1995

10 V/m, 900MHz and 1.89GHz.

Immunity to Conducted Disturbances Induced by Radio Frequency Fields

Per IEC 61000-4-6: 1996, Level 3,

Disturbing test voltage: 10 V

Power Frequency Magnetic Field Immunity

Per IEC 61000-4-8: 1994, Level 5,

100A/m applied continuously,

1000A/m applied for 3s.

Per IEC 61000-4-9: 1993, Level 5,

1000A/m applied in all planes.

Per IEC 61000-4-10: 1993, Level 5,

100A/m applied in all planes at 100kHz/1MHz with a burst duration of 2s.

Conducted Emissions

Per EN 55022: 1998:

0.15 - 0.5MHz, 79dBμV (quasi peak) 66dBμV (average)

0.5 - 30MHz, 73dBμV (quasi peak) 60dBμV (average).

Radiated Emissions

Per EN 55022: 1998:

30 - 230MHz, 40dBμV/m at 10m measurement distance

230 - 1GHz, 47dBμV/m at 10m measurement distance.

EU DIRECTIVES

EMC Compliance

Per 2004/108/EC:

Compliance to the European Commission Directive on EMC is demonstrated using a Technical File. Product Specific Standards were used to establish conformity:

EN50263: 2000

Product Safety

Per 2006/95/EC:

Compliance with European Commission Low Voltage Directive, (LVD) is demonstrated using a Technical File. A product specific standard was used to establish conformity.

EN 60255-27: 2005

R&TTE Compliance

Radio and Telecommunications Terminal Equipment (R&TTE) directive 99/5/EC. Compliance demonstrated by compliance to the Low Voltage Directive, 2006/95/EC, down to zero volts by reference to safety standards. Applicable to rear communications ports.

CE 2004/108/EC

MECHANICAL ROBUSTNESS

Vibration Test

Per IEC 60255-21-1: 1996

Response Class 2

Endurance Class 2

Shock and Bump

Per IEC 60255-21-2: 1995

Shock response Class 2

Shock withstand Class 1

Bump Class 1

Seismic Test

Per IEC 60255-21-3: 1995 Class 2

THIRD PARTY COMPLIANCES

(UL/CUL)

c UL us File Number: E202519

(Complies with Canadian and US requirements).

Energy Networks Association (ENA)

Certificate Number:	128 Issue 3
Assessment Date:	18-04-2007

PROTECTION FUNCTIONS

Performance Data

Distance Protection

All quoted operating times include the closure of the trip output contact.

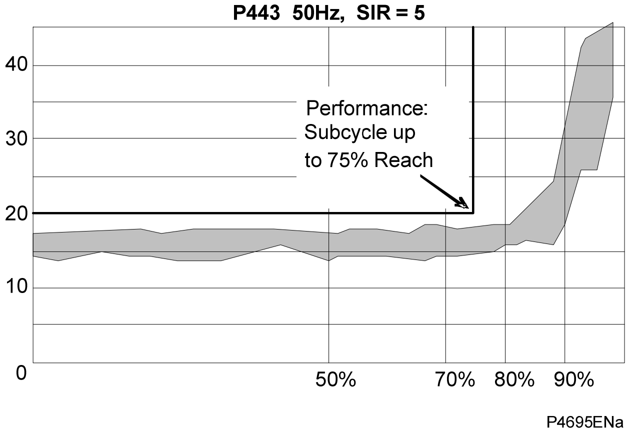
The following tripping characteristics, show operating time versus reach percentage, for faults close to line angle

50Hz Operation

Minimum tripping time:	13ms	(SIR = 5)
Typical tripping time:	17ms	(SIR = 5)
	17.5ms	(SIR = 30)

100% of faults up to 75% of Zone 1 reach setting trip subcycle at SIR=5.

99% of faults up to 75% of Zone 1 reach setting trip subcycle at SIR=30.

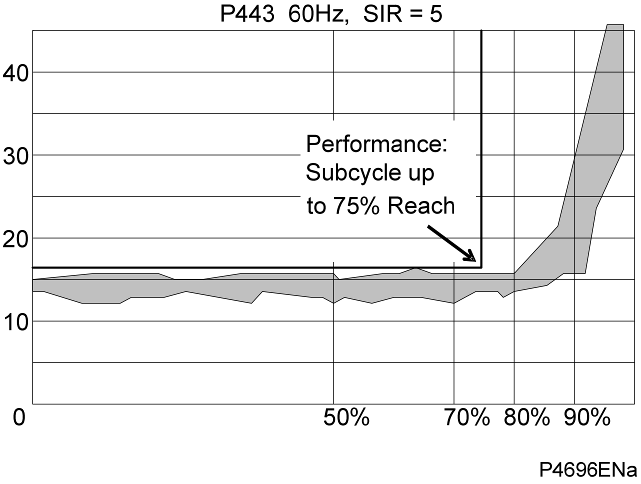


60Hz Operation

Minimum tripping time:	13ms	(SIR = 5)
Typical tripping time:	14ms	(SIR = 5)
	16ms	(SIR = 30)

100% of faults up to 75% of Zone 1 reach setting trip subcycle at SIR=5.

88% of faults up to 75% of Zone 1 reach setting trip subcycle at SIR=30.



Accuracy

Characteristic shape, up to SIR = 30:

±5%	for on-angle fault (the set line angle)
±10%	for off-angle

(Example: For a 70 degree set line angle, injection testing at 40 degrees would be referred to as “off-angle”).

Zone time delay deviations:

±20ms or 2%, whichever is greater.

Sensitivity

Settings < 5/In Ω: (0.05In*5/(setting*In)) ±5%
Settings > 5/In Ω: 0.05 In ±5%

Out Of Step

Accuracy of zones and timers as per distance operating range: up to 7Hz.

Phase and Ground (Earth) Overcurrent

Three Phase Overcurrent Protection

Accuracy
Additional tolerance X/R ratios:
±5% over X/R 1…90
Overshoot: <30 ms

Inverse Time Characteristic

Accuracy

Pick-up: Setting ±5%
Drop-off: 0.95 x setting ±5%
Minimum trip level for IDMT elements:
1.05 x Setting ± 5%
Inverse time stages:
±40ms or 5%, whichever is greater
Definite time stages:
±40ms or 2%, whichever is greater
Repeatability: 5%
Directional boundary accuracy:
±2° with hysteresis <3°
Additional tolerance due to increasing X/R ratios:
±5% over the X/R ratio from 1 to 90.
Overshoot of overcurrent elements: <30ms

Earth/Sensitive Fault Protection

Earth Fault
DT Pick-up: Setting ±5%
Minimum IDMT Trip level: 1.05 x Setting ±5%
Drop-off: 0.95 x Setting ±5%
IDMT shape: ±5% or 40ms whichever is greater *
IEEE reset: ±10% or 40ms whichever is greater
DT operation: ±2% or 50ms whichever is greater
DT reset: ±2% or 50ms whichever is greater
Repeatability: ±5%
* Reference conditions TMS = 1, TD = 1 and IN > setting of 1A, operating range 2-20In

SEF

Pick-up: Setting ±5%
Drop-off: 0.95 x Setting ±5%
Minimum trip level of IDMT elements:
1.05 x Setting ±5%
IDMT characteristic shape:
±5% or 40ms whichever is greater*
IEEE reset:
±17.5% or 60ms whichever is greater
DT operation:
±2% or 50ms whichever is greater
DT reset:
±5% or 50ms whichever is greater
Repeatability: 5%
* Reference conditions TMS = 1
TD = 1, and IN> setting of 100mA, accuracy operating range 2-20Is

REF

Pick-up: Setting formula ±5%
Drop-off: 0.80 x setting formula ±5%
Operating time: <60ms
High pick up: Setting ±5%
High operating time: <30ms
Repeatability: <15%

Wattmetric SEF

Pick-up P=0W: ISEF> ±5% or 5mA
Pick-up P>0W: P> ±5%
Drop-off P=0W: (0.95 x ISEF >) ±5% or 5mA
Drop-off P>0W: 0.9 x P> ±5%
Boundary accuracy: ±5% with 1° hysteresis
Repeatability: 1%

Polarizing Quantities

VN> and V2> Level detectors:
Pick-up: ±10%
Resetting ratio: 0.9
I2> Level detector:
Pick-up: ±10%
Resetting ratio: 0.9

Negative Sequence Overcurrent

Accuracy

Pick-up:	Setting ±5%
Drop-off:	0.95 x setting

Definite time operation:
±60ms or 2%, whichever is greater
Repeatability: 1%
Directional boundary accuracy:
±2° with hysteresis <1°
Reset: <35ms

Under Voltage

Accuracy

DT Pick-up:	Setting ±2%
IDMT Pick-up:	0.98 x setting ±2%
Drop-off:	1.02 x setting ±2%

Definite time operation:
±40ms or 2%, whichever is greater
Repeatability: 1%
IDMT characteristic shape:
±40ms or 2%, whichever is greater
Reset: <75ms

Over Voltage

Accuracy

DT Pick-up:	Setting ±1%
IDMT Pick-up:	1.02 x setting ±2%
Drop-off:	0.98 x setting ±2%

Definite time operation:
±40ms or 2%, whichever is greater
Repeatability: 1%
IDMT characteristic shape:
±40ms or 2%, whichever is greater
Reset: <75ms

Neutral Displacement/Residual Over Voltage

Accuracy

DT Pick-up:	Setting ±5%
IDMT Pick-up:	1.05 x setting ±5%
Drop-off:	0.95 x setting ±5%

Definite time operation:
±20ms or 2%, whichever is greater
Instantaneous operation: <50ms
Repeatability: 10%
IDMT characteristic shape:
±60ms or 5%, whichever is greater
Reset: <35ms

Circuit Breaker Fail and Undercurrent

Accuracy

Pick-up: ±10% or 0.025In, whichever is greater
Operating time: <12ms
Timers: ±2ms or 2%, whichever is greater
Reset: <15ms
Broken conductor logic

Accuracy

Pick-up:	Setting ±2.5%
Drop-off:	0.95 x setting ±2.5%

Definite time operation:
±50ms or 2%, whichever is greater
Reset: <25ms

Thermal Overload

Accuracy

Thermal alarm pick-up:
Calculated trip time ±10%
Thermal overload pick-up:
Calculated trip time ±10%
Cooling time accuracy ±15% of theoretical
Repeatability: <5%
* Operating time measured with applied current of 20% above thermal setting.

Voltage Transformer Supervision

Accuracy

Fast block operation: <1 cycle
Fast block reset: <1.5 cycles
Time delay: ±20ms or 2%, whichever is greater

Current Transformer Supervision

Accuracy

IN> Pick-up:	Setting ±5%
VN< Pick-up:	Setting ±5%
IN> Drop-off:	0.9 setting ±5%

VN< Drop-off:
(1.05 x setting) ±5% or 1V, whichever is greater
Time delay operation:
Setting ±2% or 20ms, whichever is greater
CTS block operation: <1 cycle
CTS reset: <35ms

CB State Monitoring and Condition Monitoring

Accuracy

Timers: ±20ms or 2%, whichever is greater
Broken current accuracy: ±5%

Programmable Scheme Logic

Accuracy

Output conditioner timer:
Setting ±20ms or 2%, whichever is greater
Dwell conditioner timer:
Setting ±20ms or 2%, whichever is greater
Pulse conditioner timer:
Setting ±20ms or 2%, whichever is greater

Auto-Reclose and Check Synchronism

Accuracy

Timers:
Setting ±20ms or 2%, whichever is greater

Measurements and Recording Facilities

Accuracy

Typically ±1%, but ±0.5% between 0.2 - 2In/Vn
Current: 0.05 to 3In
Accuracy: ±1.0% of reading
Voltage: 0.05 to 2Vn
Accuracy: ±1.0% of reading
Power (W): 0.2 to 2Vn and 0.05 to 3In
Accuracy: ±5.0% of reading at unity power factor
Reactive power (Vars):
0.2 to 2Vn to 3In
Accuracy: ±5.0% of reading at zero power factor
Apparent power (VA):
0.2 to 2Vn 0.05 to 3In
Accuracy: ±5.0% of reading
Energy (Wh): 0.2 to 2Vn 0.2 to 3In
Accuracy: ±5.0% of reading at zero power factor
Energy (Varh): 0.2 to 2Vn 0.2 to 3In
Accuracy: ±5.0% of reading at zero power factor
Phase accuracy: 0° to 360°
Accuracy: ±0.5%
Frequency: 45 to 65Hz
Accuracy: ±0.025Hz

IRIG-B and Real Time Clock

Performance accuracy

(for modulated and un-modulated versions)
Real time clock accuracy: < ±2 seconds/day

Enhanced Disturbance Records

For Software Version 57 and earlier

Maximum record duration: 50 seconds
No of records: minimum 5 at 10 second each,
maximum 50 at 1 second each
(8 records of 3 seconds each via IEC60870-5-103 protocol)
Accuracy
Magnitude and relative phases:
±5% of applied quantities
Duration: ±2%
Trigger position:
±2% (minimum Trigger 100ms)

For Software Version A0/B0 and later

Maximum record duration: 3 seconds
Maximum pre-trigger time 500 milliseconds
Extracted over: CS103, IEC61850 and COURIER
Maximum pre-trigger time using CS103 on a 60Hz system: 461 milliseconds
No of records: minimum 5 at 10 second each,
maximum 50 at 1 second each
(8 records of 3 seconds each via IEC60870-5-103 protocol)
Accuracy
Magnitude and relative phases:
±5% of applied quantities
Duration: ±2%
Trigger position:
±2% (minimum Trigger 100ms)

Fault Locator

Accuracy

Fault location:
±2% of line length (under reference conditions)*
* Reference conditions solid fault applied on line.

Event, Fault & Maintenance Records

The most recent records are stored in battery-backed memory, and can be extracted via the communication port or be viewed on the front panel display.
No of Event Records:
Up to 512 time tagged event records.
No of Fault Records: Up to 15
No of Maintenance Records: Up to 10

PLANT SUPERVISION

Accuracy

Timers: ±2% or 20ms whichever is greater
Broken current accuracy: ±5%

Timer Accuracy

Timers: ±2% or 40ms whichever is greater
Reset time: <30ms

Undercurrent Accuracy

Pick-up: ±10% or 25mA whichever is greater
Operating time: <20ms
Reset: <25ms

INTERMICOM64 Fiber Optic Teleprotection

End-end operation. Table below shows bit transfer time.
For multiplexed links, ‘MUX’ denotes the multiplexer delay.

IM64 Cmd	Applic.	Typical Delay (ms)	Max. (ms)	Note
Permissive	Direct Fiber	3 to 7	9	No Noise
	via MUX	5 to 8 + MUX	12 + MUX	BER ≤10-3
Dir. Intertrip	Direct Fiber	4 to 8	10	No Noise
	via MUX	6 to 8 + MUX	13 + MUX	BER ≤10-3

BER = Bit error rate for channel

Ethernet Data (where applicable)

100 Base FX interface

Transmitter optical characteristics

(TA = 0°C to 70°C, VCC = 4.75 V to 5.25 V)

Parameter	Sym	Min.	Typ.	Max.	Unit
Output Optical Power BOL 62.5/125 µm, NA = 0.275 Fiber EOL	PO	-19 -20	-16.8	-14	dBm avg.
Output Optical Power BOL 50/125 µm, NA = 0.20 Fiber EOL	PO	-22.5 -23.5	-20.3	-14	dBm avg.
Optical Extinction Ratio				10 -10	% dB
Output Optical Power at Logic “0” State	PO (“0”)			-45	dBm avg.

BOL - Beginning of life
EOL - End of life

Receiver optical characteristics

(TA = 0°C to 70°C, VCC = 4.75 V to 5.25 V)

Parameter	Sym	Min.	Typ.	Max.	Unit
Input Optical Power Minimum at Window Edge	PIN Min. (W)		-33.5	-31	dBm avg.
Input Optical Power Minimum at Eye Center	PIN Min. (C)		-34.5	-31.8	Bm avg.
Input Optical Power Maximum	PIN Max.	-14	-11.8		dBm avg.

SETTINGS, MEASUREMENTS AND RECORDS LIST

Settings List

Global Settings (System Data):

Language: English/French/German/Spanish
English/French/German/Russian
Chinese/English/French
Frequency: 50/60Hz

Circuit Breaker Control (CB Control)

CB Control by:
Disabled
Local
Remote
Local+remote
Opto
Opto+local
Opto+remote
Opto+rem+local
Close pulse time: 0.10…10.00s
Trip pulse time: 0.10…5.00s

P443 Specific CB Control Settings

Man close t max: 0.01…9999.00s
Man close delay: 0.01…600.00s
CB healthy time: 0.01…9999.00s
Check sync time: 0.01…9999.00s
Reset lockout by: User interface/CB close
Man close RstDly: 0.10…600.00s
Single pole A/R: Disabled/Enabled
Three pole A/R: Disabled/Enabled
CB Status Input:
None
52A 3 pole
52B 3 pole
52A & 52B 3 pole
52A 1 pole
52B 1 pole
52A & 52B 1 pole

P446 Specific CB Control Settings

Man Close Delay: 0.01…600s
CB Healthy Time: 0.01…9999s
Check Sync. Time: 0.01…9999s
Rst CB mon LO By: User Interface/CB Close
CB mon LO RstDly: 0.1…600s
CB1 Status Input:
None
52A 3 pole
52B 3 pole
52A & 52B 3 pole
52A 1 pole
52B 1 pole
52A & 52B 1 pole
CB Status Time 0.1 ... 5s
CB2 Status Input:
None
52A 3 pole
52B 3 pole
52A & 52B 3 pole
52A 1 pole
52B 1 pole
52A & 52B 1 pole
Res AROK by UI: Enabled/Disabled
Res AROK by NoAR: Enabled/Disabled
Res AROK by Ext: Enabled/Disabled
Res AROK by TDly: Enabled/Disabled
Res AROK by TDly: 1.0…9999s
Res LO by CB IS: Enabled/Disabled
Res LO by UI: Enabled/Disabled
Res LO by NoAR: Enabled/Disabled
Res LO by ExtDDB: Enabled/Disabled
Res LO by TDelay: Enabled/Disabled
LO Reset Time: 1…9999s

Date and Time

IRIG-B Sync: Disabled/Enabled
Battery Alarm: Disabled/Enabled
LocalTime Enable: Disabled/Fixed/Flexible
LocalTime Offset: -720...720
DST Enable: Disabled or Enabled
DST Offset: 30...60
DST Start: First, Second, Third, Fourth, Last
DST Start Day:
Monday, Tuesday, Wednesday, Thursday, Friday, Saturday
DST Start Month:
January, February, March, April, May, June, July, August, September, October, November, December
DST Start Mins: 0...1425
DST End: First, Second, Third, Fourth, Last
DST End Day:
Monday, Tuesday, Wednesday, Thursday, Friday, Saturday
DST End Month:
January, February, March, April, May, June, July, August, September, October, November, December
DST End Mins: 0...1425
RP1 Time Zone: UTC or Local
RP2 Time Zone: UTC or Local
DNPOE Time Zone: UTC or Local
Tunnel Time Zone: UTC or Local

Configuration

Setting Group:	
Select via Menu	
Select via Opto	
Active Settings:	Group 1/2/3/4
Setting Group 1:	Disabled/Enabled
Setting Group 2:	Disabled/Enabled
Setting Group 3:	Disabled/Enabled
Setting Group 4:	Disabled/Enabled
Distance:	Disabled/Enabled
Directional E/F:	Disabled/Enabled
Overcurrent:	Disabled/Enabled
Neg Sequence O/C:	Disabled/Enabled
Broken Conductor:	Disabled/Enabled
Earth Fault:	Disabled/Enabled
SEF/REF Prot'n:	Disabled/Enabled
Residual O/V NVD:	Disabled/Enabled
Thermal Overload:	Disabled/Enabled
Power Swing Block:	Disabled/Enabled
Volt Protection:	Disabled/Enabled
Freq Protection:	Disabled/Enabled
df/dt Protection:	Disabled/Enabled
CB Fail:	Disabled/Enabled
Supervision:	Disabled/Enabled
System Checks:	Disabled/Enabled
Auto-Reclose:	Disabled/Enabled
Input Labels:	Invisible/Visible
Output Labels:	Invisible/Visible
CT & VT Ratios:	Invisible/Visible
Record Control:	Invisible/Visible
Disturb Recorder:	Invisible/Visible
Measure't Setup:	Invisible/Visible
Comms Settings:	Invisible/Visible
Commission Tests:	Invisible/Visible
Setting Values:	Primary/Secondary
Control Inputs:	Invisible/Visible
Ctrl I/P Config:	Invisible/Visible
Ctrl I/P Labels:	Invisible/Visible
Direct Access:	Disabled/Enabled
InterMiCOM:	Disabled/Enabled
InterMiCOM64 Fiber:	Disabled/Enabled
Function Key:	Invisible/Visible
LCD Contrast:	(Factory pre-set)

CT and VT Ratios

P443 CT and VT Ratio Settings:

Main VT Primary:	100V...1MV
Main VT Sec'y:	80...140V
C/S VT Primary:	100V...1MV
C/S VT Secondary:	80...140V
Phase CT Primary:	1A…30kA
Phase CT Sec'y:	1A/5A
SEF CT Primary:	1A…30kA
SEF CT Sec'y:	1A/5A
MComp CT Primary:	1A…30kA
MComp CT Sec'y:	1A/5A
C/S Input:	
A-N	
B-N	
C-N	
A-B	
B-C	
C-A	
A-N/1.732	
B-N/1.732	
C-N/1.732	
Main VT Location:	Line/Bus
CT Polarity:	Standard /Inverted
SEF CT Polarity:	Standard /Inverted
M CT Polarity:	Standard /Inverted

P446 CT and VT Ratio Settings

Main VT Primary:	100V…1000 kV
Main VT Sec'y:	80…140V
CB1 CS VT Prim'y:	100V…1000 kV
CB1 CS VT Sec'y:	80…140V
CB2 CS VT Prim'y:	100V…1000 kV
CB2 CS VT Sec'y:	80…140V
Phase CT Primary:	1A…30kA
Phase CT Sec'y:	1…5A
SEF CT Primary:	1A…30kA
SEF CT Secondary:	1…5A
MComp CT Primary:	1…30k
MComp CT Sec'y:	1…5A
CS Input:	A-N, B-N, C-N, A-B, B-C, C-A
CT1 Polarity:	Standard/Inverted
CT2 Polarity:	Standard/Inverted
SEF CT Polarity:	Standard/Inverted
M CT Polarity:	Standard/Inverted
CB1 CS VT PhShft:	-180…+180 deg
CB1 CS VT Mag.:	0.2…3
CB2 CS VT PhShft:	-180…+180 deg
CB2 CS VT Mag.:	0.2…3

Sequence of Event Recorder (Record Control)

Alarm Event: Disabled/Enabled
Relay O/P Event: Disabled/Enabled
Opto Input Event: Disabled/Enabled
General Event: Disabled/Enabled
Fault Rec Event: Disabled/Enabled
Maint Rec Event: Disabled/Enabled
Protection Event: Disabled/Enabled
DDB 31 - 0: (up to):
DDB 1791 - 1760:

Binary function link strings, selecting which DDB signals will be stored as events, and which will be filtered out.

Oscillography (Disturb Recorder)

For Software Releases prior to B0 (i.e. 57 ans earlier):

Duration: 0.10…10.50s
Trigger Position: 0.0…100.0%
Trigger Mode: Single/Extended
Analog Channel 1: (up to):
Analog Channel 12:

Disturbance channels selected from:
IA, IB, IC, IN, IN Sensitive, VA, VB, VC, IM, V CheckSync (P443 and P446) and IA2, IB2, IC2 and VCheckSync2 (P446 only)

Digital Input 1: (up to):
Digital Input 32:

Selected binary channel assignment from any DDB status point within the relay (opto input, output contact, alarms, starts, trips, controls, logic…).

Input 1 Trigger: (up to):
Input 32 Trigger: No Trigger/Trigger

For Software Release B0:

Duration: 0.10…3.00s
Trigger Position: 0.0…16.7% (B0 - A)
0.0…50.0% (B0 - B)
Trigger Mode: Single/Extended
Analog Channel 1: (up to):
Analog Channel 12:

Disturbance channels selected from:
IA, IB, IC, IN, IN Sensitive, VA, VB, VC, V CheckSync

Digital Input 1: (up to):
Digital Input 128:

Selected binary channel assignment from any DDB status point within the relay (opto input, output contact, alarms, starts, trips, controls, logic…).

Input 1 Trigger: (up to):
Input 32 Trigger: No Trigger/Trigger

Note *The B0 software release introduces the Enhanced Disturbance Recorder (DR) feature. This increases the number of digital channels to 128.*

Measured Operating Data (Measure't Setup)

Default Display:
3Ph + N Current
3Ph Voltage
Power
Date and Time
Description
Plant Reference
Frequency
Access Level
Local Values: Primary/Secondary
Remote Values: Primary/Secondary
Measurement Ref: VA/VB/VC/IA/IB/IC
Measurement Mode: 0/1/2/3
Fix Dem Period: 1…99mins
Roll Sub Period: 1…99mins
Num Sub Periods: 1…15
Distance Unit: Miles/Kilometers
Fault Location: Distance
Ohms
% of Line
Remote 2 Values: Primary/Secondary

Communications

- RP1 Protocol:
  - Courier
  - IEC870-5-103
  - DNP3.0
  - IEC61850

Courier Protocol:

- RP1 Address: 0…255
- RP1 InactivTimer: 1…30mins
- RP1 PhysicalLink:
  - Copper
  - Fiber Optic
- RP1 Port Config:
  - K Bus
  - EIA(RS)485
- RP1 Comms Mode:
  - IEC60870 FT1.2 Frame
  - IEC60870 10-Bit Frame
- RP1 Baud Rate:
  - 9600 bits/s
  - 19200 bits/s
  - 38400 bits/s

IEC870-5-103 Protocol:

- RP1 Address: 0…255
- RP1 InactivTimer: 1…30mins
- RP1 Baud Rate:
  - 9600 bits/s
  - 19200 bits/s
- RP1 Meas Period: 1…60s
- RP1 PhysicalLink:
  - Copper
  - Fiber Optic
- RP1 CS103 Blocking:
  - Disabled
  - Monitor Blocking
  - Command Blocking

DNP3.0 Protocol: EIA(RS)485

- RP1 Address: 0…65519
- RP1 Baud Rate:
  - 1200 bits/s
  - 2400 bits/s
  - 4800 bits/s
  - 9600 bits/s
  - 19200 bits/s
  - 38400 bits/s
- RP1 Parity: Odd/Even/None
- RP1 PhysicalLink:
  - Copper
  - Fiber Optic
- RP1 Time Sync: Disabled/Enabled
- Meas Scaling: Primary/Secondary/Normalized
- Message Gap: 0…50ms
- DNP Need Time: 1...30mins
- DNP App Fragment: 100...2048
- DNP App Timeout: 1...120s
- DNP SBO Timeout: 1...10s
- DNP Link Timeout: 0.1...60s

DNP3.0 Protocol: (Ethernet)

- DNP Time Sync: Disabled/Enabled
- Meas Scaling: Primary/Secondary/Normalized
- NIC Tunl Timeout: 1...30mins
- NIC Link Report: Alarm/Event/None
- NIC Link Timeout: 0.1...60s
- DNP Need time: 1...30mins
- DNP App Fragment: 100...2048
- DNP App Timeout: 1...120s
- DNP SBO Timeout: 1...10s
- DNP Link Timeout: 0.1...60s

IEC61850 Protocol: (Ethernet)

- NIC Tunl Timeout: 1...30mins
- NIC Link Report: Alarm/Event/None
- NIC Link Timeout: 0.1...60s

Optional Additional Second Rear Communication (Rear port2 (RP2))

- RP2 Protocol: Courier (fixed)
- RP2 Port Config:
  - Courier over EIA(RS)232
  - Courier over EIA(RS)485
  - K-Bus
- RP2 Comms. Mode:
  - IEC60870 FT1.2 Frame
  - 10-Bit NoParity
- RP2 Address: 0…255
- RP2 InactivTimer: 1…30mins
- RP2 Baud Rate:
  - 9600 bits/s
  - 19200 bits/s
  - 38400 bits/s

COMMISSION TESTS

Monitor Bit 1: (up to):
Monitor Bit 8:
Binary function link strings, selecting which DDB signals have their status visible in the Commissioning menu, for test purposes.
Test Mode:
Disabled
Test Mode
Blocked Contacts
Test Pattern:
Configuration of which output contacts are to be energized when the contact test is applied.
Contact Test: No Operation,
Apply Test,
Remove Test
Test LEDs: No Operation
Apply Test
Test Auto-reclose: No Operation
Trip 3 Pole
Trip Pole A
Trip Pole B
Trip Pole C
Static Test Mode: Disabled/Enabled
Loopback Mode: Disabled
External
Internal
IM64 TestPattern:
Configuration of which InterMiCOM64 commands are to be set high or low for a loopback test.
IM64 Test Mode
Enabled/Disabled

Circuit Breaker Condition Monitoring (CB Monitor Setup)

P443 CB monitor setup

Broken I^: 1.0…2.0
I^ Maintenance: Alarm
Disabled/Enabled
I^ Maintenance: 1…25000
I^ Lockout: Alarm Disabled/Enabled
I^ Lockout: 1…25000
No. CB Ops Maint: Alarm
Disabled/Enabled
No. CB Ops Maint: 1…10000
No. CB Ops Lock: Alarm
Disabled/Enabled
No. CB Ops Lock: 1…10000
CB Time Maint: Alarm
Disabled/Enabled
CB Time Maint: 0.005…0.500s
CB Time Lockout: Alarm
Disabled/Enabled
CB Time Lockout: 0.005…0.500s
Fault Freq. Lock: Alarm
Disabled/Enabled
Fault Freq. Count: 1…9999
Fault Freq. Time: 0…9999s

P446 CB monitor setup:

CB1 Broken I^: 1…2
CB1 I^ Maintenance: Alarm Disabled/Enabled
CB1 I^ Maintenance: 1…25000In^
CB1 I^ Lockout:Alarm Disabled/Enabled
CB1 I^ Lockout:1…25000In^
No. CB1 Ops. Maint.: Alarm Disabled/Enabled
No. CB1 Ops. Maint.: 1…10000
No. CB1 Ops. Lock: Alarm Disabled/Enabled
No. CB1 Ops. Lock: 1…10000
CB1 Time Maint.: Alarm Disabled/Enabled
CB1 Time Maint.: 0.005…0.5s
CB1 Time Lockout: Alarm Disabled/Enabled
CB1 Time Lockout: 0.005…0.5s
CB1 Fault Freq. Lock: Alarm Disabled/Enabled
CB1 Flt Freq. Count: 1…9999
CB1 Flt Freq. Time: 0…9999s
CB2 Broken I^: (up to)
CB2 Flt Freq. Time:
All settings selected from the same ranges as per the first controlled circuit breaker, CB1.

Optocoupled Binary Inputs (Opto Config.)

Global threshold:
24 - 27V
30 - 34V
48 - 54V
110 - 125V
220 - 250V
Custom
Opto Input 1: (up to):
Opto Input #. (# = max. opto no. fitted):
Custom options allow independent thresholds to be set per opto, from the same range as above.
Filter Control:
Binary function link string, selecting which optos will have an extra 1/2 cycle noise filter, and which will not.
Characteristics:
Standard 60% - 80%
50% - 70%

Control Inputs into PSL (Ctrl. I/P Config.)

Hotkey Enabled:
Binary function link string, selecting which of the control inputs will be driven from Hotkeys.
Control Input 1: (up to):
Control Input 32: Latched/Pulsed
Ctrl Command 1:(up to):
Ctrl Command 32:
ON/OFF
SET/RESET
IN/OUT
ENABLED/DISABLED

EIA(RS)232 Teleprotection (INTERMiCOM Comms.)

Source Address: 0…10
Received Address: 0…10
Data Rate:
600 Baud
1200 Baud
2400 Baud
4800 Baud
9600 Baud
19200 Baud
Loopback Mode: Disabled/Internal/External
Test Pattern:
Configuration of which InterMiCOM signals are to be energized when the loopback test is applied.

INTERMiCOM Conf.

IM Msg Alarm Lvl: 0.1…100.0%
IM1 Cmd Type: Disabled/Direct/Blocking, Permissive (up to):
IM8 Cmd Type: Disabled/Direct/Blocking, Permissive
IM1 FallBackMode: Default/Latched
(up to):
IM8 FallBackMode: Default/Latched
IM1 DefaultValue: 0/1
(up to):
IM8 DefaultValue: 0/1
IM1 FrameSyncTim: 1ms…1.5 s
(up to):
IM8 FrameSyncTim: 1ms…1.5 s

FUNCTION KEYS

Fn. Key Status 1: (up to):
Fn. Key Status 10: Disable
Lock
Unlock/Enable
Fn. Key 1 Mode: (up to):
Fn. Key 10 Mode: Toggled/Normal
Fn. Key 1 Label:(up to):
Fn. Key 10 Label:
User defined text string to describe the function of the particular function key.

IED CONFIGURATOR

Switch Conf. Bank: No Action/Switch Banks

IEC 61850 GOOSE

GoEna: Disabled/Enabled
Test Mode: Disabled/Pass Through/Forced
VOP Test Pattern: 0x00000000... 0xFFFFFFFF
Ignore Test Flag: No/Yes

PROT COMMS./IM64

Scheme Setup:
2 Terminal/
Dual Redundant/
3 Terminal
Address: 0-0, 1-A…20-A, 1-B….20-B
Address: 0-0, 1-A…20-A, 1-B….20-B, 1-C…20-C
Comm Mode: Standard/IEEE C37.94
Baud Rate Ch 1: 56kbits/s or 64kbits/s
Baud Rate Ch 2: 56kbits/s or 64kbits/s
Clock Source Ch1: Internal/External
Clock Source Ch2: Internal/External
Ch1 N*64kbits/s: Auto, 1, 2, 3... 12
Ch2 N*64kbits/s: Auto, 1, 2, 3... 12
Comm Fail Timer: 0.1s...600s
Comm Fail Mode:
Ch 1 Failure/
Ch 2 Failure/
Ch 1 or Ch 2 Fail/
Ch 1 and Ch 2 Fail
Channel Timeout: 0.1s...10s
Alarm Level: 0%...100%
Prop Delay Stats: Disabled/Enabled
MaxCh 1 PropDelay: 1m...50ms
MaxCh 2 PropDelay: 1m...50ms
IM1 Cmd Type: Direct/Permissive
IM1 FallBackMode: Default/Latching
IMx(x=1 to 8) DefaultValue: 0 or 1
The IM1 - IM8s setting are common to both Ch1 and Ch2 (i.e. if IM1 DefaultValue is set to 0, it will be 0 on Ch1 and on Ch2)

Control Input User Labels (Ctrl. I/P Labels)

Control Input 1: (up to):
Control Input 32:
User defined text string to describe the function of the particular control input.

Settings in Multiple Groups

Note: All settings here onwards apply for setting groups # = 1 to 4.

PROTECTION FUNCTIONS

Line Parameters

GROUP # (for # = 1 to 4)
Line Length (km): 0.30…1000.00km
Line Length (miles): 0.20…625.00mi
Line Impedance: 0.05…500.00/In Ω
Line Angle: 20…90°
Residual Comp: 0.00…10.00
Residual Angle: -180…90°
Mutual Comp: Disabled/Enabled
KZm Mutual Set: 0.00…10.00
KZm Mutual Angle: -180…90°
Mutual cut-off (k): 0.0…2.0
Phase Sequence:
Standard ABC
Reverse ACB
CB Tripping Mode (per CB as appropriate):
3 Pole
1 and 3 Pole
Line Charging Y: 0.00…10.00ms

Distance Setup

Setting Mode: Simple/Advanced

Phase Distance

Phase Chars.: Mho/Quadrilateral
Quad Resistance: Common/Proportional
Fault Resistance: 0.05…500.00/In Ω
Zone 1 Ph Status: Disabled/Enabled
Zone 1 Ph Reach: 10…1000% of line
Zone 2 Ph Status: Disabled/Enabled
Zone 2 Ph Reach: 10…1000% of line
Zone 3 Ph Status: Disabled/Enabled
Zone 3 Ph Reach: 10…1000% of line
Zone 3 Ph Offset: Disabled/Enabled
Z3Ph Rev Reach: 10…1000% of line
Zone P Ph Status: Disabled/Enabled
Zone P Ph Dir.: Forward/Reverse
Zone P Ph Reach: 10…1000% of line
Zone 4 Ph Status: Disabled/Enabled
Zone 4 Ph Reach: 10…1000% of line

Ground Distance

Ground Chars.: Mho/Quadrilateral
Quad Resistance: Common/Proportional
Fault Resistance: 0.05…500.00/In Ω
Zone1 Gnd Status: Disabled/Enabled
Zone1 Gnd Reach: 10…1000% of line
Zone2 Gnd Status: Disabled/Enabled
Zone2 Gnd Reach: 10…1000% of line
Zone3 Gnd Status: Disabled/Enabled
Zone3 Gnd Reach: 10…1000% of line
Zone3 Gnd Offset: Disabled/Enabled
Z3Gnd Rev Reach: 10…1000% of line
ZoneP Gnd Status: Disabled/Enabled
ZoneP Gnd Direction: Forward/Reverse
ZoneP Gnd Reach: 10…1000% of line
Zone4 Gnd Status: Disabled/Enabled
Zone4 Gnd Reach: 10…1000% of line
Digital Filter:
Standard
Special Applics
CVT Filters:
Disabled
Passive
Active
SIR Setting: (for CVT): 5…60
Load Blinders: Disabled/Enabled
Load/B Impedance: 0.10…500.00/In Ω
Load/B Angle: 15…65°
Load Blinder V<: 1.0…70.0V (ph-g)
Distance Polarizing: 0.2…5.0

Delta Direction

Delta Status Disabled/Enabled
AidedDeltaStatus:
Disabled
Phase only
Ground only
Phase + Ground
Delta Char Angle: 0°...90°
Delta V Fwd: 0.1…30 V
Delta V Rev: 0.5….30 V
Delta I Fwd: 0.1In..10In
Delta I Rev: 0.051In..10In

Distance Elements - Phase Distance

Z1 Ph. Reach: 0.05…500.00/In Ω
Z1 Ph. Angle: 20…90°
R1 Ph. Resistive: 0.05…500.00/In Ω
Z1 Tilt Top Line: -30…30°
Z1 Ph. Sensit. Iph>1: 0.050…2.000 In
Z2 Ph. Reach: 0.05…500.00/In Ω
Z2 Ph. Angle: 20…90°
Z2 Ph Resistive: 0.05…500.00/In Ω
Z2 Tilt Top Line: -30…30°
Z2 Ph. Sensit. Iph>2: 0.050…2.000 In
Z3 Ph. Reach: 0.05…500.00/In Ω
Z3 Ph. Angle: 20…90°
Z3' Ph Rev Reach: 0.05…500.00/In Ω
R3 Ph Res. Fwd.: 0.05…500.00/In Ω
R3' Ph Res. Rev.: 0.05…500.00/In Ω
Z3 Tilt Top Line: -30…30°
Z3 Ph. Sensit. Iph>3: 0.050…2.000 In
ZP Ph. Reach: 0.05…500.00/In Ω
ZP Ph. Angle: 20…90°
ZP Ph Resistive: 0.05…500.00/In Ω
ZP Tilt Top line:-30…30°
ZP Ph. Sensit. Iph>P: 0.050…2.000In
Z4 Ph. Reach: 0.05…500.00/In Ω
Z4 Ph. Angle: 20…90°
Z4 Ph Resistive: 0.05…500.00/In Ω
Z4 Tilt Top line: -30…30°
Z4 Ph. Sensit. Iph>4: 0.050…2.000 In

Ground Distance Parameters

Z1 Gnd. Reach:0.05…500.00/In Ω
Z1 Gnd. Angle: 20…90°
Z1 Dynamic Tilt: Disabled or Enabled
Z1 Tilt top line: -30°...30°
kZN1 Res. Comp.: 0.00…10.00
kZN1 Res. Angle: -180…90°
kZm1 Mut. Comp.: 0.00…10.00
kZm1 Mut. Angle: -180…90°
R1 Gnd. Resistive: 0.05…500.00/In Ω
Z1 Sensit Ignd>1: 0.050…2.000 In
Z2 Gnd. Reach:0.05…500.00/In Ω
Z2 Gnd. Angle: 20…90°
Z2 Dynamic Tilt: Disabled or Enabled
Z2 Tilt top line: -30°...30°
kZN2 Res. Comp.: 0.00…10.00
kZN2 Res. Angle: -180…90°
kZm2 Mut. Comp: 0.00…10.00
kZm2 Mut. Angle: -180…90°
R2 Gnd Resistive: 0.05…500.00/In Ω
Z2 Sensit Ignd>2: 0.050…2.000 In
Z3 Gnd. Reach:0.05…500.00/In Ω
Z3 Gnd. Angle: 20…90°
Z3 Dynamic Tilt: Disabled or Enabled
Z3 Tilt top line: -30°...30°
Z3' Gnd Rev Rch: 0.05…500.00/In Ω
kZN3 Res. Comp.: 0.00…10.00
kZN3 Res. Angle: -180…90°
kZm3 Mut. Comp.: 0.00…10.00
kZm3 Mut. Angle: -180…90°
R3 Gnd Res. Fwd: 0.05…500.00/In Ω
R3 Gnd Res. Rev: 0.05…500.00/In Ω
Z3 Sensit Ignd>3: 0.050…2.000 In
ZP Ground Reach: 0.05…500.00/In Ω
ZP Ground Angle: 20…90°
ZP Dynamic Tilt: Disabled or Enabled
ZP Tilt top line: -30°...30°
kZNP Res. Comp.: 0.00…10.00
kZNP Res. Angle: -180…90°
kZmP Mut. Comp.: 0.00…10.00
kZmP Mut. Angle: -180…90°
RP Gnd Resistive: 0.05…500.00/In Ω
ZP Sensit Ignd>P: 0.050…2.000 In
Z4 Gnd. Reach:0.05…500.00/In Ω
Z4 Gnd. Angle: 20…90°
Z4 Dynamic Tilt: Disabled or Enabled
Z4 Tilt top line: -30°...30°
kZN4 Res. Comp.: 0.00…10.00
kZN4 Res. Angle: -180…90°
kZm4 Mut. Comp.: 0.00…10.00
kZm4 Mut. Angle: -180…90°
R4 Gnd. Resistive: 0.05…500.00/In Ω
Z4 Gnd Sensitivity: 0.050…2.000 In

Scheme Logic

Basic scheme

Zone 1 Tripping:
Disabled/
Phase only/
Ground only/
Phase and Ground
tZ1 Ph. Delay: 0s...10s
tZ1 Gnd. Delay: 0s...10s
Zone 2 Tripping:
Disabled/
Phase only/
Ground only/
Phase and Ground
tZ2 Ph. Delay: 0s...10s
tZ2 Gnd. Delay: 0s…10s
Zone 3 Tripping:
Disabled/
Phase only/
Ground only/
Phase and Ground
tZ3 Ph. Delay: 0s...10s
tZ2 Gnd. Delay: 0s...10s
Zone P Tripping:
Disabled/
Phase only/
Ground only/
Phase and Ground
tZP Ph. Delay: 0s...10s
tZP Gnd. Delay: 0s...10s
Zone 4 Tripping:
Disabled/
Phase only/
Ground only/
Phase and Ground
tZ4 Ph. Delay: 0s...10s
tZ4 Gnd. Delay: 0s...10s

Aided scheme 1

Aid 1 Selection:
Disabled/
PUR/
PUR Unblocking/
POR/
POR/
Unblocking/
Blocking 1/
Blocking 2/
Prog Unblocking/
Programmable
Aid 1 Distance:
Disabled/
Phase Only/
Ground only/
Phase and Ground
Aid 1 Dist. Dly: 0s...1s
Unblocking Delay: 0s...0.1s
Aid 1 DEF: Disabled/Enabled
Aid 1 DEF Dly: 0s...1s
Aid 1 DEF Trip: 1/3 Pole
Aided 1 Delta: Disabled/Enabled
Aided1 Delta dly: 0s...1s
Aided1 DeltaTrip: 1/3 Pole
tREV Guard: 0s...0.15s
Unblocking Delay: 0s...0.1s
Send on Trip: Aided/Z1, Any Trip or None
Weak Infeed: Disabled/Echo/Echo and Trip
WI Sngl Pole Trp: Disabled/Enabled
WI V< Thresh: 10V...70V
WI Trip Delay: 0s...1s
Custom Send Mask:
Bit 0 = Z1 Gnd/Bit 1 = Z2 Gnd/Bit 2 = Z4 Gnd/Bit 3 = Z1 Ph/Bit 4 = Z2 Ph/Bit 5 = Z4 Ph/Bit 6 = DEF Fwd/Bit 7 = DEF Rev/Bit
Custom Time PU: 0s...1s
Custom Time DO: 0s...1s

Aided scheme 2

(As per aided scheme 1)

Trip on Close

SOTF Status:
Disabled/Enabled Pole Dead/Enabled ExtPulse/En Pdead + Pulse
SOTF Delay: 0.2s...1000s
SOTF Tripping:
Bit 0 = Zone 1/Bit 1 = Zone 2/Bit 2 = Zone 3/Bit 3 = Zone P/Bit 4 = Zone 4/ Bit5=CNV
TOR Status Disabled/Enabled
TOR Tripping:
Bit 0 = Zone 1/Bit 1 = Zone 2/Bit 2 = Zone 3/Bit 3 = Zone P/Bit 4 = Zone 4/ Bit5=CNV
TOC Reset Delay: 0.1s...2s
TOC Delay 0.05s…0.2s
SOTF Pulse: 0.1s...10s

Z1 Extension

Z1 Ext Scheme:
Disabled/Enabled/En. On Ch1 Fail/En. On Ch2 Fail/En All Ch Fail/En. anyCh Fail
Z1 Ext Ph: 100%...200%
Z1 Ext Gnd: 100%...200%

Loss of Load

LOL Scheme:
Disabled/Enabled/En. On Ch1 Fail/En. On Ch2 Fail/En All Ch Fail/En. Any Ch Fail
LOL <I: 0.05 x In...1 x In
LOL Window: 0.01s 0.1s Phase

Phase Overcurrent (Overcurrent)

- I>1 Status:
  - Disabled
  - Enabled
  - Enabled VTS
- I>1 Function:
  - DT
  - IEC S Inverse
  - IEC V Inverse
  - IEC E Inverse
  - UK LT Inverse
  - IEEE M Inverse
  - IEEE V Inverse
  - IEEE E Inverse
  - US Inverse
  - US ST Inverse
- I>1 Directional:
  - Non-Directional
  - Directional Fwd
  - Directional Rev
- I>1 Current Set: 0.08…4.00 In
- I>1 Time Delay: 0.00…100.00s
- I>1 TMS: 0.025…1.200
- I>1 Time Dial: 0.01…100.00
- I>1 Reset Char: DT/Inverse
- I>1 tRESET: 0.00…100.00s
- I>2 Status (up to):
- I>2 tRESET
  - All settings and options chosen from the same ranges as per the first stage overcurrent, I>1.
- I>3 Status:
  - Disabled
  - Enabled
  - Enabled VTS
- I>3 Directional:
  - Non-Directional
  - Directional Fwd
  - Directional Rev
- I>3 Current Set: 0.08…32.00 In
- I>3 Time Delay: 0.00…100.00s
- I>4 Status (up to):
- I>4 Time Delay
  - All settings and options chosen from the same ranges as per the third stage overcurrent, I>3.
- I> Char Angle: -95…95°
- I> Blocking:
  - Binary function link string, selecting which overcurrent elements (stages 1 to 4) will be blocked if VTS detection of fuse failure occurs.

Negative Sequence Overcurrent (Neg Seq O/C)

- I2>1 Status: Enabled/Disabled
- I2>1 Function:
  - Disabled
  - DT
  - IEC S Inverse
  - IEC V Inverse
  - IEC E Inverse
  - UK LT Inverse
  - IEEE M Inverse
  - IEEE V Inverse
  - IEEE E Inverse
  - US Inverse
  - US ST Inverse
- I2>1 Direction:
  - Non-Directional
  - Directional Fwd
  - Directional Rev
- I2>1 Current Set: 0.08…4.00 In
- I2>1 Time Delay: 0.00…100.00s
- I2>1 TMS: 0.025…1.200
- I2>1 Time Dial: 0.01…100.00
- I2>1 Reset Char.: DT/Inverse
- I2>1 tRESET: 0.00…100.00s
- I2>2 Status (up to):
- I2>2 tRESET
  - All settings and options chosen from the same ranges as per the first stage overcurrent, I2>1.
- I2>3 Status:
  - Disabled
  - Enabled
- I2>3 Direction:
  - Non-Directional
  - Directional Fwd
  - Directional Rev
- I2>3 Current Set: 0.08…32.00 In
- I2>3 Time Delay: 0.00…100.00s
- I2>4 Status (up to):
- I2>4 Time Delay
  - All settings and options chosen from the same ranges as per the third stage overcurrent, I2>3.
- I2> VTS Blocking:
  - Binary function link string, selecting which Neg. Seq. O/C elements (stages 1 to 4) will be blocked if VTS detection of fuse failure occurs.
- I2> Char Angle: -95…95 o
- I2> V2pol Set: 0.5…25.0 (100 – 110V)

Broken Conductor

- Broken Conductor: Disabled/Enabled
- I2/I1 Setting: 0.20…1.00
- I2/I1 Time Delay: 0.0…100.0s

Ground Overcurrent (Earth Fault)

IN>1 Status: Disabled
Enabled
Enabled VTS
IN>1 Function: DT
IEC S Inverse
IEC V Inverse
IEC E Inverse
UK LT Inverse
IEEE M Inverse
IEEE V Inverse
IEEE E Inverse
US Inverse
US ST Inverse
IDG
IN>1 Directional: Non-Directional
Directional Fwd
Directional Rev
IN>1 Current Set: 0.08…4.00 In
IN>1 IDG Is: 1...4
IN>1 IDG Time: 1…2
IN>1 Time Delay: 0.00…100.00s
IN>1 TMS: 0.025…1.200
IN>1 Time Dial: 0.01…100.00
IN>1 Reset Char: DT/Inverse
IN>1 tRESET: 0.00…100.00s
IN>2 Status (up to):
IN>2 tRESET

All settings and options chosen from the same ranges as per the first stage ground overcurrent, IN>1.

IN>3 Status: Disabled
Enabled
Enabled VTS
IN>3 Directional: Non-Directional
Directional Fwd
Directional Rev
IN>3 Current Set: 0.08…32.00 In
IN>3 Time Delay: 0.00…100.00s
IN>4 Status (up to):
IN>4 Time Delay

All settings and options chosen from the same ranges as per the third stage ground overcurrent, IN>3.

IN> Blocking:

Binary function link string, selecting which ground overcurrent elements (stages 1 to 4) will be blocked if VTS detection of fuse failure occurs.

IN> DIRECTIONAL
IN> Char Angle: -95…95°
IN> Polarization: Zero Sequence
Neg Sequence
IN> VNpol Set: 0.5…40.0V
IN> V2pol Set: 0.5…25.0V
IN> I2pol Set: 0.02…1.00 In

Directional Aided Schemes - DEF Settings

DEF Status: Disabled/Enabled
DEF Polarizing: Zero Sequence (virtual current pol)
Neg Sequence
DEF Char Angle: -95…95°
DEF VNpol Set: 0.5…40.0V
DEF V2pol Set: 0.5…25.0V
DEF Fwd Set: 0.08…1.00 In
DEF Rev Set: 0.04…1.00 In

SEF/REF Protection

SEF/REF Options: SEF Enabled
Wattmetric SEF,
HI Z REF
ISEF>1 Function: IDMT Curve Type
Disabled
DT
IEC S Inverse
IEC V Inverse
IEC E Inverse
UK LT Inverse
IEEE M Inverse
IEEE V Inverse
IEEE E Inverse
US Inverse
US ST Inverse
IDG
ISEF>1 Directional: Non-Directional
Directional Fwd
Directional Rev
ISEF>1 Current Set: 0.005…0.1 InSEF
ISEF>1 IDG Is: 1...4
ISEF>1 IDG Time: 1…2s
ISEF>1 Time Delay: 0 s…..200s
ISEF>1 TMS: 0.025…1.2
ISEF>1 Time Dial: 0.01…100
ISEF>1 Reset Char: DT/Inverse
ISEF>1 tRESET: 0 s-100s
ISEF>2 as ISEF>1
ISEF>3 Status: Disabled
Enabled
ISEF>3 Directional: Non-Directional
Directional Fwd
Directional Rev
ISEF>3 Current Set: 0.005…0.8 InSEF
ISEF>3 Time Delay: 0 s…200s
ISEF>3 Intertrip: Enabled/Disabled
ISEF>4 as ISEF>3
ISEFN> Blocking
Bit 0 VTS Blks ISEF>1
Bit 1 VTS Blks ISEF>2
Bit 2 VTS Blks ISEF>3
Bit 3 VTS Blks ISEF>4
Bit 4 A/R Blks ISEF>3
Bit 5 A/R Blks ISEF>4
Bit 6 Not Used
Bit 7 Not Used
ISEF> Directional

ISEF> Char Angle: -95°…95° deg
ISEF> VNpol Set: 0.5…80V Wattmetric SEF
PN> Setting: 0...20InSEF W
REF
IREF>Is: 0.05In .. 1.0In

Neutral Voltage Displacement (Residual O/V NVD)

VN>1 Function: Disabled
DT
IDMT
VN>1 Voltage Set: 1…80V
VN>1 Time Delay: 0.00…100.00s
VN>1 TMS: 0.5…100.0
VN>1 tReset: 0.00…100.00s
VN>2 Status: Disabled/Enabled
VN>2 Voltage Set: 1…80V
VN>2 Time Delay: 0.00…100.00s

Thermal Overload

Characteristic: Disabled
Single
Dual
Thermal Trip: 0.08…4.00 In
Thermal Alarm: 50…100%
Time Constant 1: 1…200mins
Time Constant 2: 1…200mins

Power Swing/Out Of Step

Power Swing

Power Swing: Blocking
Indication
PSB Reset Delay: 0.05…2.00s
Zone 1 Ph PSB: (up to):
Zone 4 Ph PSB: Blocking/Allow Trip
Zone 1 Gnd PSB: (up to):
Zone 4 Gnd PSB: Blocking/Allow Trip
PSB Unblocking: Disabled/Enabled
PSB Unblock Delay: 0.1…10.0s
PSB Reset Delay: 0.5…2.0s

Out Of Step

OST (Out of Step Tripping) Mode: Disabled
Predictive and OST Trip
OST Trip
Predictive OST
Z5 Fwd Reach: 0.1…500.00/In Ω
Z6 Fwd Reach: 0.1…500.00/In Ω
Z5' Rev Reach: 0.1…500.00/In Ω
Z6' Rev Reach: 0.1…500.00/In Ω
R5 Res. Fwd: 0.1…200.00/In Ω
R6 Res. Fwd: 0.1…200.00/In Ω
R5' Res. Rev: -0.1…-200.00/In Ω
R6' Res. Rev: -0.1…-200.00/In Ω
α Blinder Angle:20…90°
Delta t Time Setting: 0.02s…1s
Tost Time Delay Setting: 0s…1s

Undervoltage Protection

V< Measur't Mode:
    V<1 & V<2 Ph-Ph,
    V<1 & V<2 Ph-N,
    V<1Ph-Ph V<2Ph-N,
    V<1Ph-N V<2Ph-Ph.
V< Operate Mode:
    V<1 & V<2 Any Ph,
    V<1 & V<2 3Phase,
    V<1AnyPh V<2 3Ph,
    V<1 3Ph V<2AnyPh.
V<1 Function:
    Disabled
    DT
    IDMT
V<1 Voltage Set: 10…120V
V<1 Time Delay: 0.00…100.00s
V<1 TMS: 0.5…100.0
V<1 Poledead Inh: Disabled/Enabled
V<2 Status: Disabled/Enabled
V<2 Voltage Set: 10…120V
V<2 Time Delay: 0.00…100.00s
V<2 Poledead Inh: Disabled/Enabled

Overvoltage Protection

V> Measur't Mode:
    V>1 & V>2 Ph-Ph,
    V>1 & V>2 Ph-N,
    V>1Ph-Ph V>2Ph-N,
    V>1Ph-N V>2Ph-Ph.
V> Operate Mode:
    V>1 & V>2 Any Ph,
    V>1 & V>2 3Phase,
    V>1AnyPh V>2 3Ph,
    V>1 3Ph V>2AnyPh.
V>1 Function:
    Disabled
    DT
    IDMT
V>1 Voltage Set: 60…185V
V>1 Time Delay: 0.00…100.00s
V>1 TMS: 0.5…100.0
V>2 Status: Disabled/Enabled
V>2 Voltage Set: 60…185V
V>2 Time Delay: 0.00…100.00s
V1>1 Cmp Funct:
    Disabled
    DT
    IDMT
V1>1 Cmp Vlt Set: 60…110V
V1>1 Cmp Tim Dly: 0.00…100.00s
V1>1 CmpTMS: 0.5…100.0
V1>2 Cmp Status: Disabled/Enabled
V1>2 Vlt Set: 60…110V
V1>2 CmpTim Dly: 0.00…100.00s

Under-Frequency Protection

F<1 Status: Disabled/Enabled
F<1 Setting: 45.00…65.00Hz
F<1 Time Delay: 0.00…100.00s
F<2 Status (up to):
F<4 Time Delay
All settings and options chosen from the same ranges as per the 1st stage.
F< Function Link:
Binary function link string, selecting which frequency elements (stages 1 to 4) will be blocked by the pole-dead logic.

Over-Frequency Protection

F>1 Status: Disabled/Enabled
F>1 Setting: 45.00…65.00Hz
F>1 Time Delay: 0.00…100.00s
F>2 Status (up to):
F>2 Time Delay
All settings and options chosen from the same ranges as per the 1st stage.

Rate-of-Change of Frequency Protection (df/dt Protection)

df/dt Avg. Cycles: 6…12
df/dt>1 Status: Disabled/Enabled
df/dt>1 Setting: 0.1…10.0Hz/s
df/dt>1 Dir'n.: Negative/Positive/Both
df/dt>1 Time: 0.00…100.00s
df/dt>2 Status: (up to):
df/dt>4 Time
All settings and options chosen from the same ranges as per the 1st stage.

Circuit Breaker Fail

CB Fail 1 Status: Disabled/Enabled
CB Fail 1 Timer: 0.00…10.00s
CB Fail 2 Status: Disabled/Enabled
CB Fail 2 Timer: 0.00…10.00s
Volt Prot Reset:
- I< Only
- CB Open & I<
- Prot Reset & I<

Ext Prot Reset:
- I< Only
- CB Open & I<
- Prot Reset & I<
- WI Prot Reset:
- Disabled/Enabled Undercurrent

I< Current Set: 0.02…3.20 In
ISEF< Current Set: 0.001…0.8 InSEF
Poledead
V<: 10…40V

Supervision

VT Supervision (VTS):

VTS Mode:
Measured + MCB, Measured Only or MCB Only
VTS Status: Disabled/Blocking/Indication
VTS Reset Mode: Manual/Auto
VTS Time Delay: 1s...10s
VTS I> Inhibit: 0.08....32 x In
VTS I2> Inhibit: 0.05...0.5 x In
Inrush Detection
I> 2nd Harmonic: 10%...100%
Weak Infeed Blk
WI Inhibit: Disabled/Enabled
I0/I2 Setting: 2...3

CT Supervision (CTS):

CTS Mode: Disabled/Enabled
CTS Status: Restrain, Indication,
CTS Reset Mode: Manual or Auto
CTS Time Delay: 0s...10s
CTS VN< Inhibit: 0.5V...22V
CTS IN> Set: 0.08...4 x In

System Checks

Bus-Line Synchronism and Voltage Checks (System Checks)

P443 System Checks:

Voltage Monitors
Live Voltage: 1.0…132.0V
Dead Voltage: 1.0…132.0V
Synchrocheck (Check Synch)
CS1 Status: Disabled/Enabled
CS1 Phase Angle: 0…90°
CS1 Slip Control:
- None
- Timer
- Frequency
- Both

CS1 Slip Freq: 0.02…1.00Hz
CS1 Slip Timer: 0.0…99.0s
CS2 Status (up to):
CS2 Slip Timer
All settings and options chosen from the same ranges as per the first stage CS1 element.
CS Undervoltage: 10.0…132.0V
CS Overvoltage: 60.0…185.0V
CS Diff Voltage: 1.0…132.0V
CS Voltage Block:
- None
- Undervoltage
- Overvoltage
- Differential
- UV & OV
- UV & DiffV
- OV & DiffV
- UV, OV & DiffV

System Split

SS Status: Disabled/Enabled
SS Phase Angle: 90…175°
SS Under V Block: Disabled/Enabled
SS Undervoltage: 10.0…132.0V
SS Timer: 0.0…99.0s

P446 System Checks:

Voltage Monitors
Live Line: 5…132V
Dead Line: 5…132V
Live Bus 1: 5…132V
Dead Bus 1: 5…132V
Live Bus 2: 5…132V
Dead Bus 2: 5…132V
CS UV: 5…120V
CS OV: 60…200V
Sys Checks CB1: Enabled/Disabled
CB1 CS Volt. Blk: V<
V>
Vdiff.>
V< and V>
V< and Vdiff>
V> and Vdiff>
V< V> and Vdiff>
None
CB1 CS1 Status: Enabled or Disabled
CB1 CS1 Angle: 0…90°
CB1 CS1 Vdiff: 1…120V
CB1 CS1 SlipCtrl: Enabled/Disabled
CB1 CS1 SlipFreq: 5mHz…2Hz
CB1 CS2 Status: Enabled/Disabled
CB1 CS2 Angle: 0…90°
CB1 CS2 Vdiff: 1…120V
CB1 CS2 SlipCtrl: Enabled/Disabled
CB1 CS2 SlipFreq: 5mHz…2Hz
CB1 CS2 Adaptive: Enabled/Disabled
CB1 CI Time: 10.0ms…0.5s
Sys Checks CB2: (up to):
CB2 CI Time:
All settings and options chosen from the same ranges as per the first controlled circuit breaker, CB1.

Manual System Checks

Num CBs: CB1 Only
CB2 Only
CB1 & CB2.
CB1M SC required: Enabled/Disabled
CB1M SC CS1: Enabled/Disabled
CB1M SC CS2: Enabled/Disabled
CB1M SC DLLB: Enabled/Disabled
CB1M SC LLDB: Enabled/Disabled
CB1M SC DLDB: Enabled/Disabled
CB2M SC required: (up to):
CB2M SC DLDB:
All settings and options chosen from the same ranges as per the first controlled circuit breaker, CB1.

Auto-Reclose

P443 Auto-Reclose:

Single Pole Shot: 1/2/3/4
Three Pole Shot: 1/2/3/4
1 Pole Dead Time: 0.05…5.00s
Dead Time 1: 0.05…100.00s
Dead Time 2: 1…1800s
Dead Time 3: 1…3600s
Dead Time 4: 1…3600s
CB Healthy Time: 1…3600s
Reclaim Time: 1…600s
AR Inhibit Time: 0.01…600.00s
Check Sync Time: 0.01…9999.00s
Z2T AR: (up to):
Z4T AR:
No Action
Initiate AR
Block AR
All time-delayed distance zones can be independently set not to act upon AR logic, to initiate a cycle, or to block.
DEF Aided AR:
Initiate AR
Block AR
Dir. Comp AR:
Initiate AR
Block AR
TOR:
Initiate AR
Block AR
I>1 AR: (up to):
I>4 AR:
No Action
Initiate AR
Block AR
All overcurrent stages can be independently set not to act upon AR logic, to initiate a cycle, or to block.
IN>1 AR: (up to):
IN>4 AR:
No Action
Initiate AR
Block AR
All ground/earth overcurrent stages can be independently set not to act upon AR logic, to initiate a cycle, or to block.
ISEF>1 AR: (up to):
ISEF>4 AR:
No Action
Initiate AR
Block AR
All ground/earth overcurrent stages can be independently set not to act upon AR logic, to initiate a cycle, or to block.

Mult Phase AR:
- Allow Autoclose
- BAR 2 and 3Ph
- BAR 3 Phase

Dead Time Start:
- Protection Op
- Protection Reset

Discrim Time: 0.10…5.00s
System Checks
CheckSync1 Close: Disabled/Enabled
CheckSync2 Close: Disabled/Enabled
LiveLine/DeadBus: Disabled/Enabled
DeadLine/LiveBus: Disabled/Enabled
DeadLine/DeadBus: Disabled/Enabled
CS AR Immediate: Disabled/Enabled
SysChk on Shot 1: Disabled/Enabled

P446 Auto-reclose:

Num CBs:
- CB1 Only
- CB2 Only
- Both CB1 & CB2

Lead/Foll AR Mode:
- L1P F1P
- L1P F3P
- L3P F3P
- L1/3P F1/3P
- L1/3P F3P
- Opto

AR Mode:
- AR 1P
- AR 1/3P
- AR 3P
- AR Opto

Leader Select By:
- Leader by Menu
- Leader by Opto
- Leader by Ctrl

Select Leader:
- Sel Leader CB1
- Sel Leader CB2

BF if LFail Cls: Enabled/Disabled
Dynamic F/L: Enabled/Disabled
AR Shots: 1…4

Multi Phase AR:
- Allow Auto-close
- BAR 2 and 3 ph
- BAR 3 Phase

Discrim Time: 5ms…5s
CB IS Time: 5…200s
CB IS MemoryTime: 10ms…1s

DT Start by Prot:
- Protection Reset
- Protection Op
- Disabled

3PDTStart WhenLD: Enabled/Disabled
DTStart by CB Op: Enabled/Disabled
Dead Line Time: 1…9999s
SP AR Dead Time: 0…10s
3P AR DT Shot 1: 10ms…300s
3P AR DT Shot 2: 1…9999s
3P AR DT Shot 3: 1…9999s
3P AR DT Shot 4: 1…9999s
Follower Time: 100ms…300s
SPAR ReclaimTime: 1…600s
3PAR ReclaimTime: 1…600s
AR CBHealthy Time: 0.01…9999s
AR CheckSync Time: 0.01…9999s

Z1 AR:
- Initiate AR
- Block AR

Dist. Aided AR:
- Initiate AR
- Block AR

Z2T AR: (up to):
Z4T AR:
- No Action
- Initiate AR
- Block AR

All time-delayed distance zones can be independently set not to act upon AR logic, to initiate a cycle, or to block.

DEF Aided AR:
- Initiate AR
- Block AR

Dir. Comp AR:
- Initiate AR
- Block AR

TOR:
- Initiate AR
- Block AR

I>1 AR: (up to):
I>4 AR:
- No Action
- Initiate AR
- Block AR

All overcurrent stages can be independently set not to act upon AR logic, to initiate a cycle, or to block.

IN>1 AR: (up to):
IN>4 AR:
- No Action
- Initiate AR
- Block AR

All ground/earth overcurrent stages can be independently set not to act upon AR logic, to initiate a cycle, or to block.

ISEF>1 AR: (up to):
ISEF>4 AR:
- No Action
- Initiate AR
- Block AR

All ground/earth overcurrent stages can be independently set not to act upon AR logic, to initiate a cycle, or to block.

Auto-reclose System Checks

CB1L SC All: Enabled/Disabled
CB1L SC Shot 1: Enabled/Disabled
CB1L SC ClsNoDly: Enabled/Disabled
CB1L SC CS1: Enabled/Disabled
CB1L SC CS2: Enabled/Disabled
CB1L SC DLLB: Enabled/Disabled
CB1L SC LLDB: Enabled/Disabled
CB1L SC DLDB: Enabled/Disabled
CB2L SC All: Enabled/Disabled
CB2L SC Shot 1: Enabled/Disabled
CB2L SC ClsNoDly: Enabled/Disabled
CB2L SC CS1: Enabled/Disabled
CB2L SC CS2: Enabled/Disabled
CB2L SC DLLB: Enabled/Disabled
CB2L SC LLDB: Enabled/Disabled
CB2L SC DLDB: Enabled/Disabled
CB1F SC All: Enabled/Disabled
CB1F SC Shot 1: Enabled/Disabled
CB1F SC CS1: Enabled/Disabled
CB1F SC CS2: Enabled/Disabled
CB1F SC DLLB: Enabled/Disabled
CB1F SC LLDB: Enabled/Disabled
CB1F SC DLDB: Enabled/Disabled
CB2F SC All: Enabled/Disabled
CB2F SC Shot 1: Enabled/Disabled
CB2F SC CS1: Enabled/Disabled
CB2F SC CS2: Enabled/Disabled
CB2F SC DLLB: Enabled/Disabled
CB2F SC LLDB: Enabled/Disabled
CB2F SC DLDB: Enabled/Disabled

OPTO INPUT LABELS

Opto Input 1: (up to):
Opto Input xx:
(xx depending on the model number)
User defined text string to describe the function of the particular opto input.

OUTPUT LABELS

Relay 1: (up to):
Relay xx:
(xx depending on the model number):
User defined text string to describe the function of the particular relay output contact.

MEASUREMENTS LIST

Measurements 1

Iφ Magnitude
Iφ Phase Angle
Per phase (φ = A, B, C) current measurements
IN derived Mag
IN derived Angle
ISEF Mag
ISEF Angle
I1 Magnitude
I2 Magnitude
I0 Magnitude
Iφ RMS
Per phase (φ = A, B, C)
RMS current measurements
IN RMS
Vφ-φ Magnitude
Vφ-φ Phase Angle
Vφ Magnitude
Vφ Phase Angle
All phase-phase and phase-neutral voltages (φ = A, B, C).
V1 Magnitude
V2 Magnitude
V0 Magnitude
Vφ RMS
Vφ-φ RMS
All phase-phase and phase-neutral voltages (φ = A, B, C).
Frequency
CB1 CS Volt Mag
CB1 CS Volt Ang
CB1 Bus-Line Ang
CB1 CS Slip Freq
IM Magnitude
IM Phase Angle
I1 Magnitude
I1 Phase Angle
I2 Magnitude
I2 Phase Angle
I0 Magnitude
I0 Phase Angle
V1 Magnitude
V1 Phase Angle
V2 Magnitude
V2 Phase Angle
V0 Magnitude
V0 Phase Angle
CB2 CS Volt Mag (P446 only)
CB2 CS Volt Ang (P446 only)
CB2 Bus-Line Ang (P446 only)
CB2 CS Slip Freq (P446 only)
V1 Rem Magnitude
V1 Rem Phase Ang

IA CT1 Magnitude	(P446 only)
IA CT1 Phase Ang	(P446 only)
IB CT1 Magnitude	(P446 only)
IB CT1 Phase Ang	(P446 only)
IC CT1 Magnitude	(P446 only)
IC CT1 Phase Ang	(P446 only)
IA CT2 Magnitude	(P446 only)
IA CT2 Phase Ang	(P446 only)
IB CT2 Magnitude	(P446 only)
IB CT2 Phase Ang	(P446 only)
IC CT2 Magnitude	(P446 only)
IC CT2 Phase Ang	(P446 only)

Measurements 2

φ Phase Watts
φ Phase VArs
φ Phase VA
All phase segregated power measurements, real, reactive and apparent (φ = A, B, C).
3 Phase Watts
3 Phase VArs
3 Phase VA
Zero Seq Power
3Ph Power Factor
φPh Power Factor
Independent power factor measurements for all three phases (φ = A, B, C).
3Ph WHours Fwd
3Ph WHours Rev
3Ph VArHours Fwd
3Ph VArHours Rev
3Ph W Fix Demand
3Ph VArs Fix Dem
Iφ Fixed Demand
Maximum demand currents measured on a per phase basis (φ = A, B, C).
3Ph W Roll Dem
3Ph VArs Roll Dem
Iφ Roll Demand
Maximum demand currents measured on a per phase basis (φ = A, B, C).
3Ph W Peak Dem
3Ph VAr Peak Dem
Iφ Peak Demand
Maximum demand currents measured on a per phase basis (φ = A, B, C).
Thermal State

Measurements 4

Ch 1 Prop Delay
Ch 2 Prop Delay
Channel 1 Status
Channel 2 Status
Channel Status:
Bit 0-3: Not Used
Bit 4 = Mux Clk F Error
Bit 5 = Signal Lost
Bit 6 = Path Yellow
Bit 7 = Mismatch RxN
Bit 8 = Timeout
Bit 9 = Message Level
Bit 10 = Passthrough
Bit 11 = Reserved
Bit 12 = Max Prop Delay
Binary function link strings denoting channel errors, and when self-healing has been initiated in 3-terminal applications.
IM64 Rx Status
Statistics
Last Reset on
Date/Time
Ch1 No. Vald Mess
Ch1 No. Err Mess
Ch1 No. Errored s
Ch1 No. Sev Err s
Ch1 No. Dgraded m
Ch2 No. Vald Mess
Ch2 No. Err Mess
Ch2 No. Errored s
Ch2 No. Sev Err s
Ch2 No. Dgraded m
Max Ch 1 Prop Delay
Max Ch 2 Prop Delay
Clear Statistics

Circuit Breaker Monitoring Statistics

CB Operations
CB φ Operations
Circuit breaker operation counters on a per phase basis (φ = A, B, C).
Total Iφ Broken
Cumulative breaker interruption duty on a per phase basis (φ = A, B, C).
CB Operate Time
For a second circuit breaker (P446 only)
CB2 Operations
CB2 φ Operations
Circuit breaker operation counters on a per phase basis (φ = A, B, C).
CB2 Iφ Broken
Cumulative breaker interruption duty on a per phase basis (φ = A, B, C).
CB2 Operate Time

Fault Record Proforma

The following data is recorded for any relevant elements that operated during a fault, and can be viewed in each fault record.

Time & Date
Model Number:
Address:
Event Type: Fault record
Event Value
Faulted Phase:

Binary data strings for fast polling of which phase elements started or tripped for the fault recorded.

Start Elements
Trip Elements

Binary data strings for fast polling of which protection elements started or tripped for the fault recorded.

Fault Alarms

Binary data strings for fast polling of alarms for the fault recorded.

Fault Time
Active Group: 1/2/3/4
System Frequency: Hz
Fault Duration: s
CB Operate Time: s
Relay Trip Time: s
Fault Location: km/miles/Ω/%
I φPre Flt
Iφ Angle Pre Flt

Per phase record of the current magnitudes and phase angles stored before the fault inception.

IN Prefault Mag
IN Prefault Ang
IM Prefault Mag
IM Prefault Ang
Vφ Prefault Mag
Vφ Prefault Ang

Per phase record of the voltage magnitudes and phase angles stored before the fault inception.

VN Prefault Mag
VN Prefault Ang
Iφ Fault Mag
Iφ Fault Ang

Per phase record of the current magnitudes and phase angles during the fault.

IN Fault Mag
IN Fault Ang
IM Fault Mag
IM Fault Ang
Vφ Fault Mag
Vφ Fault Ang

Per phase record of the voltage magnitudes and phase angles during the fault.

VN Fault Mag
VN Fault Ang

GETTING STARTED

CHAPTER 3

Date:	02/2013
Hardware Suffix:	K/M (P443 and P446) and J/L (P445)
Software Version:	55/57/B0/D0 (P443 and P446) and 35/36/E0/F0 (P445)
Connection Diagrams:	10P44303 (SH 01 and 03) 10P44304 (SH 01 and 03) 10P44305 (SH 01 and 03) 10P44306 (SH 01 and 03) 10P445xx (xx = 01 to 04) 10P44600 10P44601 (SH 1 to 2) 10P44602 (SH 1 to 2) 10P44603 (SH 1 to 2)

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1 INTRODUCTION TO THE RELAY

1.1 User Interfaces and Menu Structure

The settings and functions of the MiCOM protection relay can be accessed both from the front panel keypad and LCD, and via the front and rear communication ports. Information on each of these methods is given in this section to describe how to start using the relay.

1.2 Introduction to the Relay

Figure 1 shows the front panel of the relay; the hinged covers at the top and bottom of the front panel are shown open. An optional transparent front cover physically protects the front panel. With the cover in place, access to the user interface is read-only. Removing the cover allows access to the relay settings and does not compromise the protection of the product from the environment.

When editing relay settings, full access to the relay keypad is needed. To remove the front panel:

1. Open the top and bottom covers, then unclip and remove the transparent cover. If the lower cover is secured with a wire seal, remove the seal.
2. Using the side flanges of the transparent cover, pull the bottom edge away from the relay front panel until it is clear of the seal tab.
3. Move the cover vertically down to release the two fixing lugs from their recesses in the front panel.

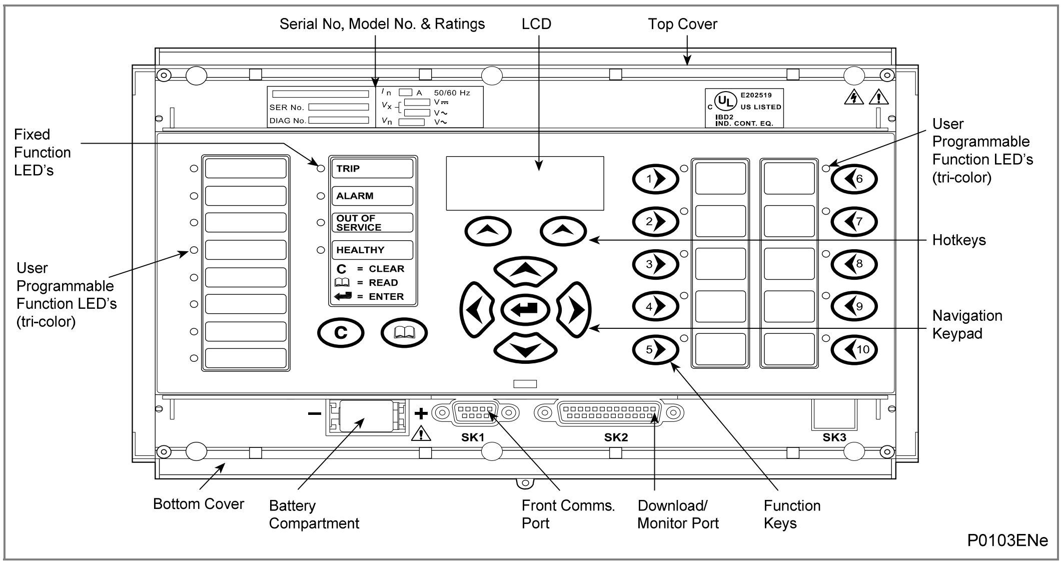
Serial No, Model No. & Ratings
LCD
Top Cover
SER No.
DIAG No.
In A 50/60 Hz
Vx V⎓
V～
Vn V～
E202519
US LISTED
IBD2
IND. CONT. EQ.
Fixed Function LED's
User Programmable Function LED's (tri-color)
TRIP
ALARM
OUT OF SERVICE
HEALTHY
C = CLEAR
= READ
= ENTER
C
1
2
3
4
5
6
7
8
9
10
User Programmable Function LED's (tri-color)
Hotkeys
Navigation Keypad
−
+
SK1
SK2
SK3
Bottom Cover
Battery Compartment
Front Comms. Port
Download/ Monitor Port
Function Keys
P0103ENe

Figure 1 - Relay front view (P44y)

Note	*Figure 1 shows the P44y case layout. The exact layout depends on the model configuration and case size.*

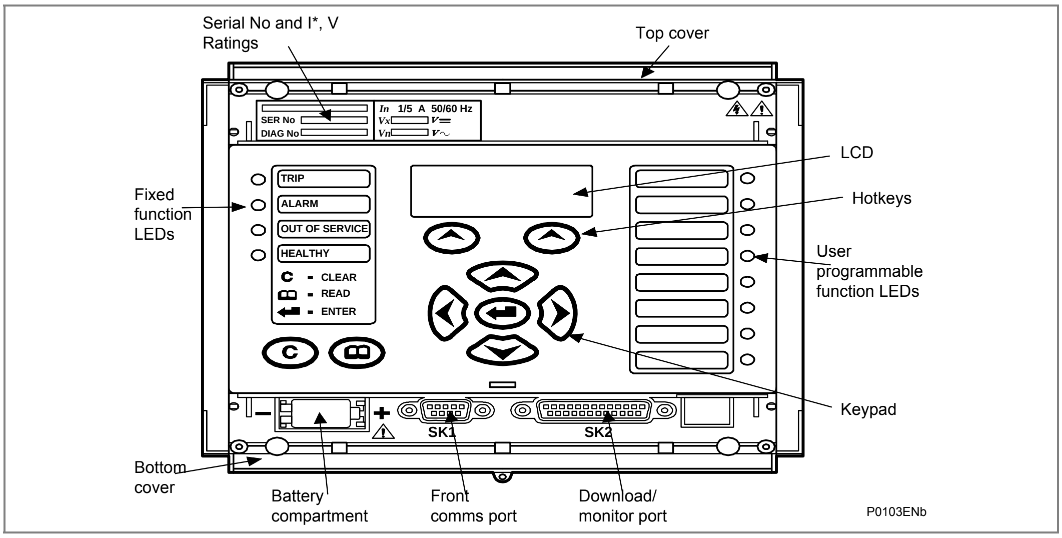
Serial No and I*, V Ratings
Top cover
SER No
DIAG No
In 1/5 A 50/60 Hz
Vx
Vn
LCD
Fixed function LEDs
TRIP
ALARM
OUT OF SERVICE
HEALTHY
C = CLEAR
= READ
= ENTER
Hotkeys
User programmable function LEDs
Keypad
SK1
SK2
Bottom cover
Battery compartment
Front comms port
Download/ monitor port
P0103ENb

Figure 2 - Relay front view (P445 with a 40TE case)

> *Note* *Figure 2 shows the P445 40TE case layout. The exact layout depends on the model configuration and case size.*

The front panel of the relay includes the following, as shown in Figure 1 and Figure 2:

- A 16-character by three-line alphanumeric Liquid Crystal Display (LCD)
- A keypad (19 keys for P443/P446 and nine keys for P445), comprising:
  - four arrow keys (◀ ▶ ▲ and ▼), an enter key (↵), a clear key (Ⓒ), a read key (📖) and two hot keys (⑦)
  - 10 (① – ⑩) programmable function keys (P443/P446)

    Function key functionality for the P443/P446. The relay front panel features control pushbutton switches with programmable LEDs that facilitate local control. Factory default settings associate specific relay functions with these 10 direct-action pushbuttons and LEDs e.g. Enable/Disable the auto-recloser function. Using programmable scheme logic, the user can readily change the default direct-action pushbutton functions and LED indications to fit specific control and operational needs.
- Hotkey functionality:
  - **SCROLL** starts scrolling through the various default displays.
  - **STOP** stops scrolling the default display.
  - **Control** of setting groups, control inputs and circuit breaker operation
- LED indicators (22 LEDs for P443/P446 and 12 LEDs for P445):
  - four fixed function LEDs,
  - programmable function LEDs on the left hand side of the front panel (eight tri-color LEDs for the P443/P446)
  - user programmable function LEDs on the right hand side associated with the function keys (10 tri-color LEDs for the P443/P446 and eight LEDs for the P445)
- Under the top hinged cover:
  - The relay serial number.
  - The relay's current and voltage rating information.

- Under the bottom hinged cover:
    - Battery compartment to hold the ½ AA-size battery which is used for memory back-up for the real time clock, event, fault and disturbance records.
    - A 9-pin female D-type front port for communication with a PC locally to the relay (up to 15m distance) via an EIA(RS)232 serial data connection.
    - A 25-pin female D-type port providing internal signal monitoring and high speed local downloading of software and language text via a parallel data connection.

1.3 LED Indications

1.3.1 Fixed Function

The four fixed-function LEDs on the left-hand side of the front panel are used to indicate the following conditions:

- **Trip (Red)** indicates that the relay has issued a trip signal. It is reset when the associated fault record is cleared from the front display. (Alternatively the trip LED can be configured to be self-resetting)*.
- **Alarm (Yellow)** flashes to indicate that the relay has registered an alarm. This may be triggered by a fault, event or maintenance record. The LED will flash until the alarms have been accepted (read), after which the LED will change to constant illumination, and will extinguish, when the alarms have been cleared.
- **Out of service (Yellow)** indicates that the relay's protection is unavailable.
- **Healthy (Green)** indicates that the relay is in correct working order, and should be on at all times. It will be extinguished if the relay's self-test facilities indicate that there is an error with the relay's hardware or software. The state of the healthy LED is reflected by the watchdog contact at the back of the relay.

To adjust the LCD contrast, from the **CONFIGURATION** column, select **LCD Contrast**. This is only needed in very hot or cold ambient temperatures.

1.3.2 Programmable LEDs

All models:

All the programmable LEDs and are suitable for alarm and trip indications as required by the user. Their functionality is assigned in the Programmable Scheme Logic (PSL) of the relay and can be latched or self-resetting.

The default mappings for the programmable LEDs are shown in Table 1.

The LEDs associated with the function keys, are used to indicate the status of the associated pushbutton's function and the default indications are shown in Table 1:

P445	*All the programmable LEDs are red when energized.*
P443/P446	*All the programmable LEDs are tri-color and can be programmed to indicate RED, YELLOW or GREEN depending on the requirements.*

LED No	Default Color	P443	P445	P446
1	Red	Dist Inst Trip	Zone 1 or Aided Trip Indication	Dist Inst Trip
2	Red	Dist Delay Trip	Z2 Trip Indication	Dist Delay Trip
3	Red	Aided DEF Trip	Zone 3 Trip Indication	Aided DEF Trip
4	Red	Aided Dir Trip	Zone 4 Trip Indication	Aided Dir Trip
5	Red	Zone 4 Trip	Aided DEF Trip Indication	Not Used
5	Amber	Not Used	Not Used	Any start
6	Yellow	AR in Progress	Not Used	Not Used
6	Red	Not Used	AR 3ph in Progress	Zone 4 Trip
7	Yellow	AR Lockout	Not Used	Test Loopback
7	Red	Not Used	AR Lockout	Not Used
8	Yellow	AR in Service	Not Used	Not Used
8	Amber	Not Used	Not Used	AR in Service
8	Red	Not Used	AR Status 3ph Indication	Not Used
F1	Red	Not Used	Not Used	CB1 A Open
F1	Green	Not Used	Not Used	CB1 A Closed
F2	Red	Not Used	Not Used	CB1 B Open
F2	Green	Not Used	Not Used	CB1 B Closed
F3	Red	Not Used	Not Used	CB1 C Open
F3	Green	Not Used	Not Used	CB1 C Closed
F4	Red	Not Used	Not Used	CB1 AR Lockout
F5	Green	Not Used	Not Used	CB1 AR Successful
F5	Amber	Not Used	Not Used	CB1 ARIP
F6	Red	Not Used	Not Used	CB2 A Open
F6	Green	Not Used	Not Used	CB2 A Closed
F7	Red	Not Used	Not Used	CB2 B Open
F7	Green	Not Used	Not Used	CB2 B Closed
F8	Red	Not Used	Not Used	CB2 C Open
F8	Green	Not Used	Not Used	CB2 C Closed
F9	Red	Not Used	Not Used	CB2 AR Lockout
F10	Green	Not Used	Not Used	CB2 AR Successful
F10	Amber	Not Used	Not Used	CB2 ARIP

Table 1 - LED numbers and default indicators for P443, P445 and P446

1.4 Relay Rear Panel

Refer to the wiring diagrams in the *Installation* chapter for complete connection details.

The Relay Rear Panel varies from one model to another:

- Relay Rear Panel for P443 and P446
- Relay Rear Panel for P445

1.4.1 Relay Rear Panel for P443 and P446

The rear panel of a relay is shown in Figure 3. All current and voltage signals, digital logic input signals and output contacts are connected at the rear of the relay. Figure 3 shows:

Slot	Board function
Slot A	Optional IRIG-B and ETHERNET - IEC 61850 - board
Slot B	Fiber communication board for InterMicom^{64}
Slot C	Analogue (CT& VT) Input Board
Slot D, E and F	Opto-isolated inputs boards
Slot J, K, L and M	Relay output contacts boards
Slot J	Power Supply/EIA(RS)485 Communications board

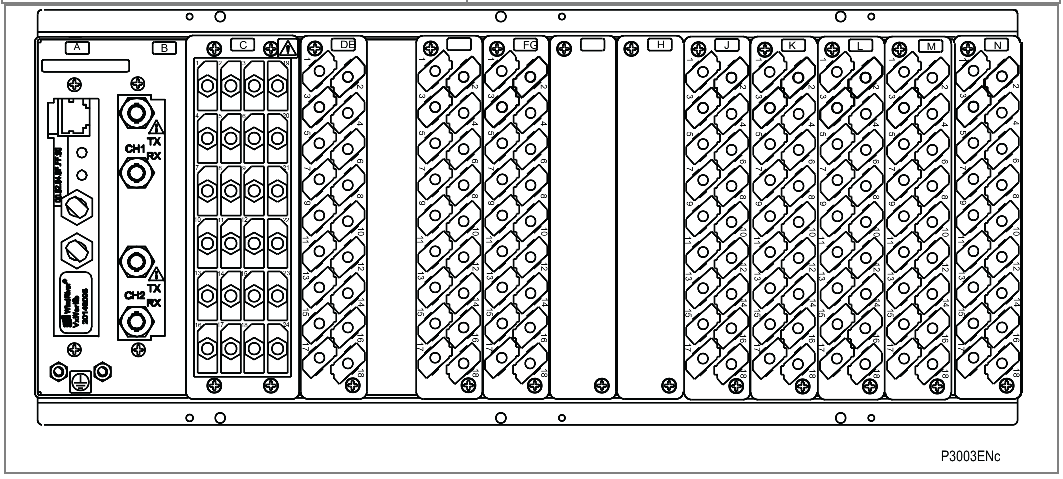

Figure 3 - Relay rear view (P443)

Note	*Figure 3 shows example P443 case layout for information purposes. The exact layout will vary depending on the model configuration.*

1.4.2 Relay Rear Panel for P445

Figure 4 shows the rear panel of the relay. All current and voltage signals, digital logic input signals and output contacts are connected at the rear of the relay.

The optional second rear communications board (slot A) contains the following.

- The IRIG-B time synchronizing input.
- The 9 pin female D connector in the middle used for second communication port.
- The 9 pin female InterMiCOM connector at the bottom.

Slot B is an optional Fiber communication board for InterMiCOM^{64} teleprotection.

Slot ref.	Board function
A	Options are: IRIG-B or (2nd RP + InterMiCOM), or both
B	InterMiCOM^{64} Fiber Communication Board (optional)
C	Analog (VT) Input Board
D	Opto-isolated Inputs (L1 - L8)
E	Relay Output Contacts (R1 - R8)
F	Power Supply and EIA(RS)485 Communications

Note *shows the P445 40TE case layout. The exact layout depends on the model configuration and case size.*

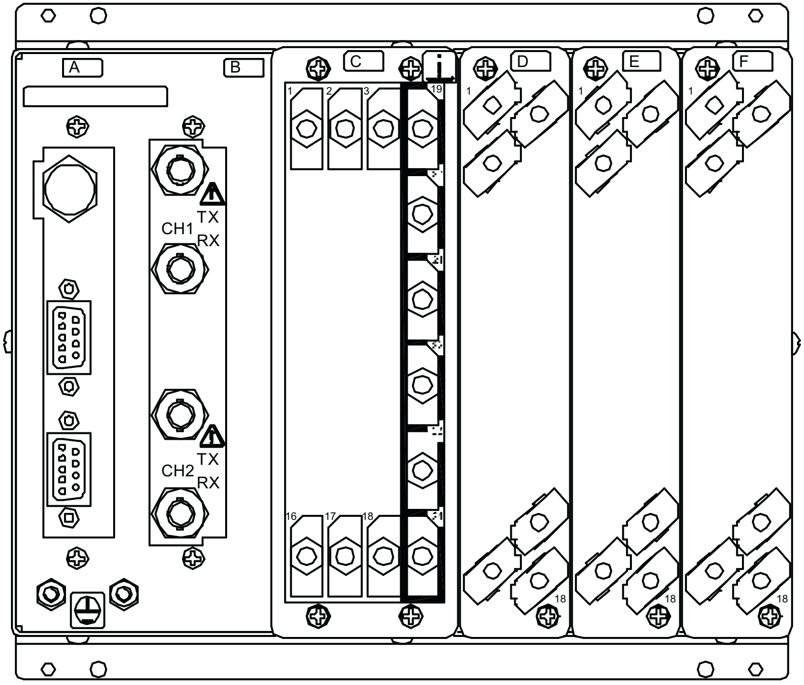

Figure 4 - P445 relay rear view (40TE)

2 RELAY CONNECTION AND POWER-UP

Before powering-up the relay, confirm that the relay power supply voltage and nominal ac signal magnitudes are appropriate for your application. The relay serial number and its current, voltage and power rating information are under the top hinged cover. The relay is available in the auxiliary voltage versions specified in Table 2:

Nominal Ranges	Operative dc Range	Operative ac Range
24 - 48V dc	19 to 65V	-
48 - 110V dc (40 - 100V ac rms) **	37 to 150V	32 to 110V
110 - 250V dc (100 - 240V ac rms) **	87 to 300V	80 to 265V
** rated for ac or dc operation		
Note *The label does not specify the logic input ratings.*		

Table 2 - Nominal ranges for dc and ac

The relay has universal opto isolated logic inputs. These can be programmed for the nominal battery voltage of the circuit where they are used. See *Universal Opto input* in the *Firmware* section for more information on logic input specifications.

> *Note* *The opto inputs have a maximum input voltage rating of 300 VDC at any setting.*

Once the ratings have been verified for the application, connect external power according to the power requirements specified on the label to perform the relay familiarization procedures. Figure 3 shows the location of the power supply terminals. See the *external connection diagrams* in the *Installation* chapter *P445/EN IN* for complete installation details, ensuring the correct polarities are observed for the dc supply.

3 USER INTERFACES AND SETTINGS OPTIONS

The relay has three user interfaces:

- The front panel user interface via the LCD and keypad
- The front port which supports Courier communication
- The rear port which supports
  K-Bus or IEC60870-5-103 or DNP3.0 or IEC 61850 + Courier through the rear EIA(RS)485 port or
  IEC 61850 + IEC60870-5-103 through the rear EIA(RS)485 port.
  The protocol for the rear port must be specified when the relay is ordered

The measurement information and relay settings which can be accessed from the three interfaces are summarized in Table 3.

	Keypad/LCD	Courier	IEC 61850	IEC870-5-103	DNP3.0
Display and modification of all settings	•	•			
Digital I/O signal status	•	•	•	•	•
Display/extraction of measurements	•	•	•	•	•
Display/extraction of fault records	•	•		•	•
Extraction of disturbance records		•	•	•	
Programmable scheme logic settings		•			
Reset of fault and alarm records	•	•		•	•
Clear event and fault records	•	•			•
Time synchronization		•	•	•	•
Control commands	•	•		•	•

Table 3 - Measurement information and relay settings

4 MENU STRUCTURE

The relay’s menu is arranged in a table. Each setting in the menu is known as a cell, and each cell in the menu may be accessed using a row and column address. The settings are arranged so that each column contains related settings, for example all disturbance recorder settings are in the same column. As shown in Figure 5, the top row of each column contains the heading that describes the settings in that column. You can only move between the columns of the menu at the column heading level.

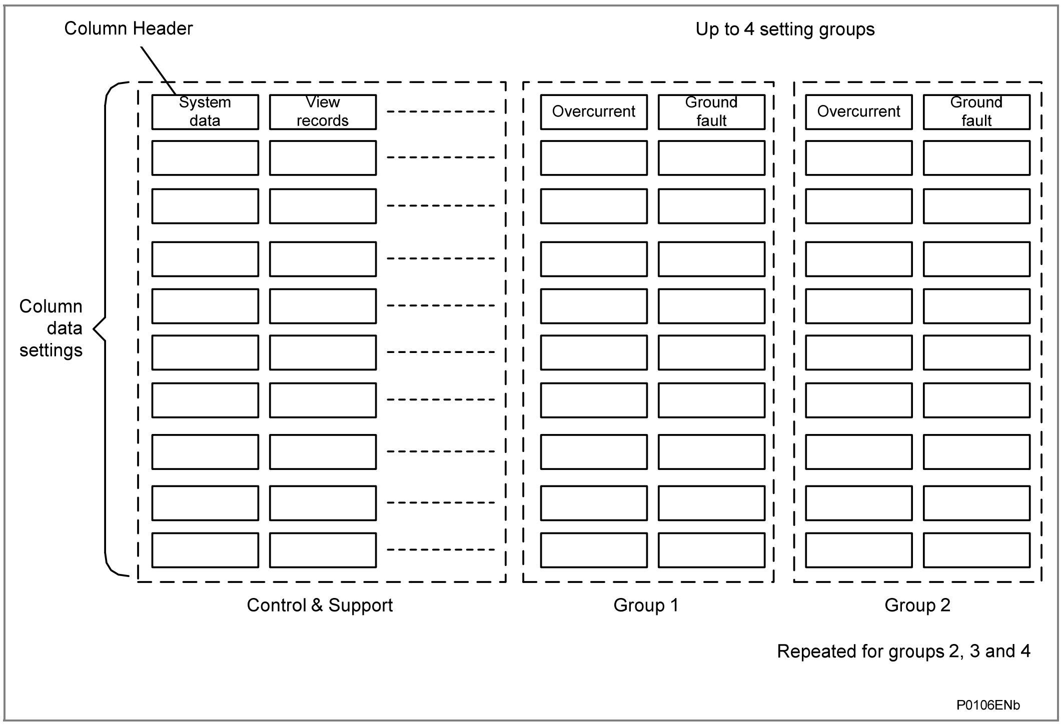
Column Header
Up to 4 setting groups
System data
View records
Overcurrent
Ground fault
Overcurrent
Ground fault
Column data settings
Control & Support
Group 1
Group 2
Repeated for groups 2, 3 and 4
P0106ENb

Figure 5 - Menu structure

The settings in the menu are in these categories;

- Protection Settings
- Disturbance Recorder settings
- Control and Support (C&S) settings.

One of two different methods is used to change a setting depending on which category the setting falls into.

- C&S settings are stored and used by the relay immediately after they are entered.
- For either protection settings or disturbance recorder settings, the relay stores the new setting values in a temporary ‘scratchpad’. It activates all the new settings together, but only after it has been confirmed that the new settings are to be adopted. This technique is employed to provide extra security, and so that several setting changes that are made within a group of protection settings will all take effect at the same time.

Additional security settings can now be obtained by using the **Cyber Security** features. This is now an option for these models:

- P44y (P443 & P446) using Software Version D0 (or later) on Hardware Suffix M
- P445 using Software Version F0 (or later) on Hardware Suffix L

4.1 Protection Settings

The protection settings include the following items:

- Protection element settings
- Scheme logic settings

There are four groups of protection settings, with each group containing the same setting cells. One group of protection settings is selected as the active group, and is used by the protection elements.

4.2 Enhanced Disturbance Recorder Settings

The enhanced Disturbance Recorder (DR) settings include the record duration and trigger position, selection of analog and digital signals to record, and the signal sources that trigger the recording.

Products covered by the following Software Versions have had their maximum number of digital channels increased to 128:

- P44y (P43 and P446) - Software Release B0 and later
- P445 - Software Release E0 and later

4.3 Control and Support Settings

The control and support settings include:

- Relay configuration settings
- VT ratio settings
- Reset LEDs
- Active protection setting group
- Password & language settings
- Communications settings
- Measurement settings
- Event & fault record settings
- User interface settings
- Commissioning settings

5 PASSWORD PROTECTION

The menu structure contains three levels of access. The level of access that is enabled determines which of the relay's settings can be changed and is controlled by entry of two different passwords. The levels of access are summarized in Table 4.

Set the "Password Control" cell to	The "Access Level" cell displays	Operations	Type of password required
0	0	**Read** - Access to all settings, alarms, event records and fault records	None
		Execute - Control Commands, e.g. circuit breaker open/close. Reset of fault and alarm conditions. Reset LEDs. Clearing of event and fault records	Level 1 Password
		Edit - All other settings	Level 2 Password
1	1	**Read** - Access to all settings, alarms, event records and fault records	None
		Execute - Control Commands, e.g. circuit breaker open/close. Reset of fault and alarm conditions. Reset LEDs. Clearing of event and fault records	None
		Edit - All other settings	Level 2 Password
2 (Default)	2 (Default)	**Read** -Access to all settings, alarms, event records and fault records	None
		Execute -Control Commands, e.g. circuit breaker open/close. Reset of fault and alarm conditions. Reset LEDs. Clearing of event and fault records	None
		Edit -All other settings	None

Table 4 - Access levels

Each of the two passwords are four characters of upper-case text. The factory default for both passwords is AAAA. Each password is user-changeable once it has been correctly entered. Entry of the password is achieved either by a prompt when a setting change is attempted, or by moving to the 'Password' cell in the 'System data' column of the menu. The level of access is independently enabled for each interface, that is to say if level 2 access is enabled for the rear communication port, the front panel access will remain at level 0 unless the relevant password is entered at the front panel.

The access level enabled by the password entry will time-out independently for each interface after a period of inactivity and revert to the default level. If the passwords are lost an emergency password can be supplied - contact Schneider Electric with the relay's serial number. The current level of access enabled for an interface can be determined by examining the 'Access level' cell in the 'System data' column, the access level for the front panel User Interface (UI), can also be found as one of the default display options.

The relay is supplied with a default access level of 2, such that no password is required to change any of the relay settings. It is also possible to set the default menu access level to either level 0 or level 1, preventing write access to the relay settings without the correct password. The default menu access level is set in the 'Password control' cell which is found in the 'System data' column of the menu (note that this setting can only be changed when level 2 access is enabled).

6 RELAY CONFIGURATION

The relay is a multi-function device that supports numerous different protection, control and communication features. In order to simplify the setting of the relay, there is a configuration settings column which can be used to enable or disable many of the functions of the relay. The settings associated with any function that is disabled are made invisible, i.e. they are not shown in the menu. To disable a function change the relevant cell in the **Configuration** column from **Enabled** to **Disabled**.

The configuration column controls which of the four protection settings groups is selected as active through the **Active settings** cell. A protection setting group can also be disabled in the configuration column, provided it is not the present active group. Similarly, a disabled setting group cannot be set as the active group.

7 FRONT PANEL USER INTERFACE (KEYPAD AND LCD)

When the keypad is exposed it provides full access to the menu options of the relay, with the information displayed on the LCD.

The ◁ ▷ △ and ▽ keys which are used for menu navigation and setting value changes include an auto-repeat function that comes into operation if any of these keys are held continually pressed. This can be used to speed up both setting value changes and menu navigation; the longer the key is held depressed, the faster the rate of change or movement becomes.

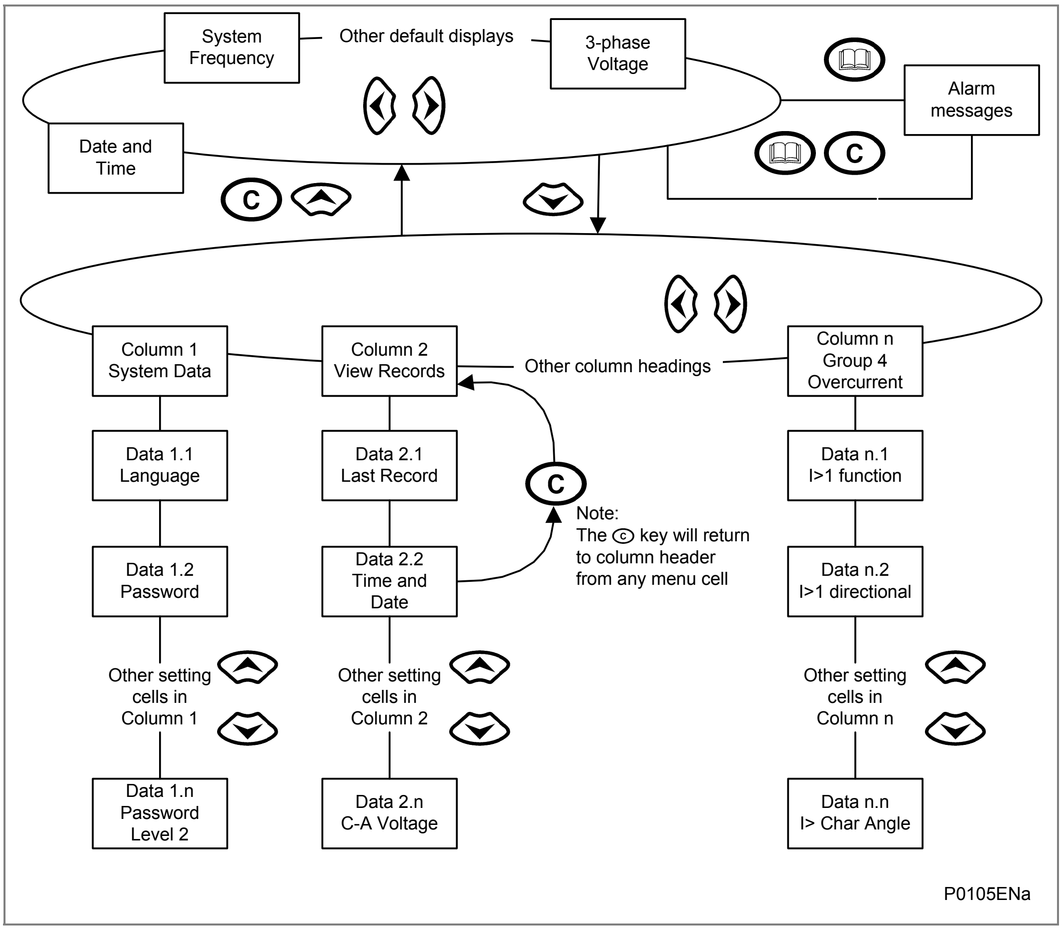
System Frequency
Other default displays
3-phase Voltage
Alarm messages
Date and Time
C
C
C
Column 1 System Data
Column 2 View Records
Other column headings
Column n Group 4 Overcurrent
Data 1.1 Language
Data 2.1 Last Record
Data n.1 I>1 function
Note:
The C key will return to column header from any menu cell
Data 1.2 Password
Data 2.2 Time and Date
Data n.2 I>1 directional
Other setting cells in Column 1
Other setting cells in Column 2
Other setting cells in Column n
Data 1.n Password Level 2
Data 2.n C-A Voltage
Data n.n I> Char Angle
P0105ENa

Figure 6 - Front panel user interface

7.1 Default Display and Menu Time-Out

The front panel menu has a default display, the contents of which can be selected from the following options in the **default display** cell of the **Measure't. setup** column:

- Date and time
- Relay description (user defined)
- Plant reference (user defined)
- System frequency
- 3-phase voltage
- Access level

From the default display it is also possible to view the other default display options using the ◁ and ▷ keys. However, if there is no keypad activity for the 15 minute timeout period, the default display will revert to that selected by the setting and the LCD backlight will turn off. If this happens any setting changes that have not been confirmed will be lost and the original setting values maintained.

Whenever there is an uncleared alarm present in the relay (e.g. fault record, protection alarm, control alarm etc.) the default display will be replaced by:

```
Alarms/Faults
Present
```

Entry to the menu structure of the relay is made from the default display and is not affected if the display is showing the **Alarms/Faults present** message.

7.2 Navigating Menus and Browsing Settings

Use the four arrow keys to browse the menu, following the structure shown in Figure 8.

1. Starting at the default display, press the △ key to show the first column heading.
2. Use the ◁ and ▷ keys to select the required column heading.
3. Use the ▽ and △ keys to view the setting data in the column.
4. To return to the column header, either hold the △ key down or press the clear key ⓒ once. It is only possible to move across columns at the column heading level.
5. To return to the default display, press the △ key or the clear key ⓒ from any of the column headings. If you use the auto-repeat function of the △ key, you cannot go straight to the default display from one of the column cells because the auto-repeat stops at the column heading.
6. Press the △ key again to go to the default display.

7.3 Navigating the Hotkey Menu

The hotkey menu can be browsed using the two keys directly below the LCD. These are known as direct access keys. The direct access keys perform the function that is displayed directly above them on the LCD. Thus, to access the hotkey menu from the default display the direct access key below the “HOTKEY” text must be pressed. Once in the hotkey menu the ⇐ and ⇒ keys can be used to scroll between the available options and the direct access keys can be used to control the function currently displayed. If neither the ⇐ or ⇒ keys are pressed with 20 seconds of entering a hotkey sub menu, the relay will revert to the default display. The clear key ⓒ will also act to return to the default menu from any page of the hotkey menu. The layout of a typical page of the hotkey menu is described below:

- The top line shows the contents of the previous and next cells for easy menu navigation
- The center line shows the function
- The bottom line shows the options assigned to the direct access keys

The functions available in the hotkey menu are listed below:

7.3.1 Setting Group Selection

The user can either scroll using <<NXT GRP>> through the available setting groups or <<SELECT>> the setting group that is currently displayed.

When the SELECT button is pressed a screen confirming the current setting group is displayed for 2 seconds before the user is prompted with the <<NXT GRP>> or <<SELECT>> options again. The user can exit the sub menu by using the left and right arrow keys.

For more information on setting group selection refer to *Changing Setting Group* section in the *Operation* section.

7.3.2 Control Inputs - User Assignable Functions

The number of control inputs (user assignable functions - USR ASS) represented in the hotkey menu is user configurable in the “CTRL I/P CONFIG” column. The chosen inputs can be SET/RESET using the hotkey menu.

For more information refer to the “*Control Inputs*” section in the *Operation* section.

7.3.3 CB Control

The CB control functionality varies from one relay to another. For a detailed description of the CB control via the hotkey menu refer to the *Circuit Breaker Control* section of the *Operation* section.

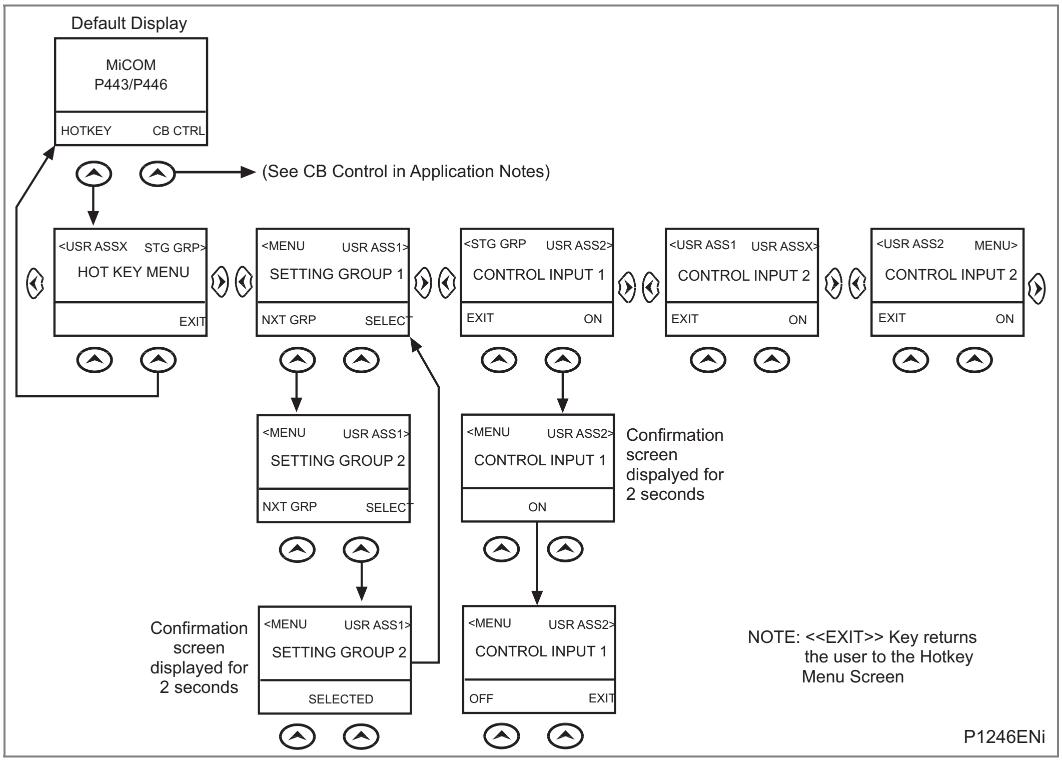
Default Display
MiCOM
P443/P446
HOTKEY
CB CTRL
(See CB Control in Application Notes)
<USR ASSX
STG GRP>
HOT KEY MENU
EXIT
<MENU
USR ASS1>
SETTING GROUP 1
NXT GRP
SELECT
<STG GRP
USR ASS2>
CONTROL INPUT 1
EXIT
ON
<USR ASS1
USR ASSX>
CONTROL INPUT 2
EXIT
ON
<USR ASS2
MENU>
CONTROL INPUT 2
EXIT
ON
<MENU
USR ASS1>
SETTING GROUP 2
NXT GRP
SELECT
<MENU
USR ASS2>
CONTROL INPUT 1
ON
Confirmation
screen
dispalyed for
2 seconds
Confirmation
screen
displayed for
2 seconds
<MENU
USR ASS1>
SETTING GROUP 2
SELECTED
<MENU
USR ASS2>
CONTROL INPUT 1
OFF
EXIT
NOTE: <<EXIT>> Key returns
the user to the Hotkey
Menu Screen
P1246ENi

Figure 7 - Hotkey menu navigation (P443/P446)

7.4 Password Entry

1. When a password is required to edit a setting, an Enter password prompt appears.

```
Enter password
**** Level 2
```

Note The password required to edit the setting is the prompt as shown above.

2. A flashing cursor shows which character field of the password can be changed. Press the ⌃ and ⌄ keys to change each character between A and Z.

3. Use the ‹ and › key to move between the character fields of the password. Press the enter key ↵ to confirm the password.

   If an incorrect password is entered, the display reverts to Enter password. A message then appears indicating that the password is correct and if so what level of access has been unlocked. If this level is sufficient to edit the selected setting, the display returns to the setting page to allow the edit to continue. If the correct level of password has not been entered, the password prompt page appears again.

4. To escape from this prompt press the clear key ⓒ. Alternatively, enter the password using System data > Password.
   If the keypad is inactive for 15 minutes, the password protection of the front panel user interface reverts to the default access level.

5. To manually reset the password protection to the default level, select System data > Password, then press the clear key instead of entering a password.

7.5 Reading and Clearing of Alarm Messages and Fault Records

One or more alarm messages appear on the default display and the yellow alarm LED flashes. The alarm messages can either be self-resetting or latched, in which case they must be cleared manually.

1. To view the alarm messages, press the read key 📖. When all alarms have been viewed but not cleared, the alarm LED change from flashing to constantly ON and the latest fault record appears (if there is one).

2. Scroll through the pages of the latest fault record, using the 📖 key. When all pages of the fault record have been viewed, the following prompt appears.

```
Press clear to
reset alarms
```

3. To clear all alarm messages, press ⓒ. To return to the display showing alarms or faults present, and leave the alarms uncleared, press 📖.

4. Depending on the password configuration settings, you may need to enter a password before the alarm messages can be cleared. See the *Password Protection* section.

5. When all alarms are cleared, the yellow alarm LED switches OFF; also the red trip LED switches OFF if it was switched ON after a trip.

6. To speed up the procedure, enter the alarm viewer using the 📖 key, then press the ⓒ key. This goes straight to the fault record display. Press ⓒ again to move straight to the alarm reset prompt, then press ⓒ again to clear all alarms.

7.6 Setting Changes

1. To change the value of a setting, go to the relevant cell in the menu, then press the enter key ↵ to change the cell value. A flashing cursor on the LCD shows the value can be changed. If a password is required to edit the cell value, a password prompt appears.
2. To change the setting value, press the ▽ or △ keys. If the setting to be changed is a binary value or a text string, select the required bit or character to be changed using the ◁ and ▷ keys.
3. Press ↵ to confirm the new setting value or the clear key ⓒ to discard it. The new setting is automatically discarded if it is not confirmed in 15 seconds.
4. For protection group settings and disturbance recorder settings, the changes must be confirmed before they are used by the relay.

   To do this, when all required changes have been entered, return to the column heading level and press the ▽ key. Before returning to the default display, the following prompt appears.

   ```
   Update settings?
   Enter or clear
   ```
5. Press ↵ to accept the new settings or press ⓒ to discard the new settings.

Note	*If the menu time-out occurs before the setting changes have been confirmed, the setting values are also discarded.*

Control and support settings are updated immediately after they are entered, without the **Update settings**? prompt.

8 FRONT COMMUNICATION PORT USER INTERFACE

The front communication port is a 9-pin female D-type connector under the bottom hinged cover. It provides EIA(RS)232 serial data communication up to 15 m with a PC, see Figure 8. This port supports the Courier communication protocol only. Courier is the communication language developed by Schneider Electric to allow communication with its range of protection relays. The front port is intended for use with the relay settings program MiCOM S1 studio which runs on Windows 98, NT4.0, 2000 or XP.

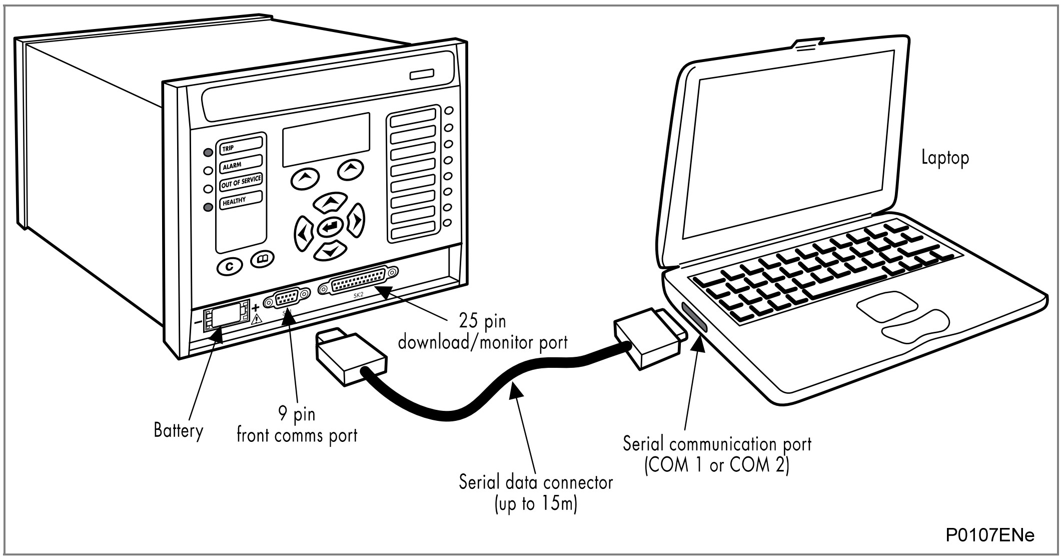
Laptop
25 pin
download/monitor port
Battery
9 pin
front comms port
Serial communication port
(COM 1 or COM 2)
Serial data connector
(up to 15m)
P0107ENe
TRIP
ALARM
OUT OF SERVICE
HEALTHY

Figure 8 - Front port connection

The relay is a Data Communication Equipment (DCE) device with the pin connections on the 9-pin front port as shown in Table 5:

Pin	Signal
2	Tx Receive data
3	Rx Transmit data
5	0V Zero volts common

Table 5 - Front port DCE pin connections

None of the other pins are connected in the relay. The relay should be connected to the serial port of a PC, usually called COM1 or COM2. PCs are normally Data Terminal Equipment (DTE) devices which have a serial port pin connection as below (if in doubt check your PC manual):

Pin	25 Way	9 Way	Signal
2	3	2	Rx Receive data
3	2	3	Tx Transmit data
5	7	5	0V Zero volts common

Table 6 - DTE devices serial port pin connections

For successful data communication, connect the Tx pin on the relay to the Rx pin on the PC, and the Rx pin on the relay to the Tx pin on the PC. See Figure 9. Normally a straight-through serial cable is required, connecting pin 2 to pin 2, pin 3 to pin 3, and pin 5 to pin 5.

Note	*A common cause of difficulty with serial data communication is connecting Tx to Tx and Rx to Rx. This could happen if a cross-over serial cable is used, connecting pin 2 to pin 3, and pin 3 to pin 2, or if the PC has the same pin configuration as the relay..*

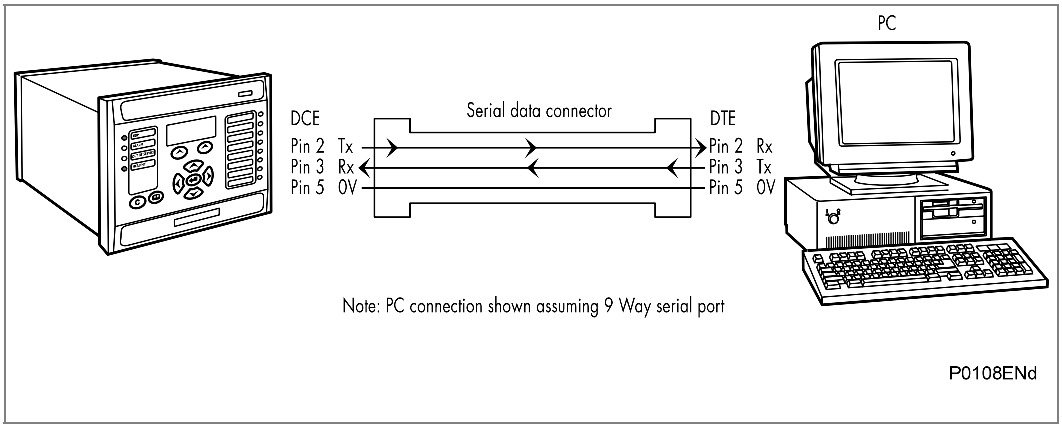

Figure 9 - PC relay signal connection

Once the physical connection from the relay to the PC is made, the PC's communication settings must be set to match those of the relay. Table 7 shows the relay's communication settings for the front port.

Protocol	Courier
Baud rate	19,200 bits/s
Courier address	1
Message format	11 bit - 1 start bit, 8 data bits, 1 parity bit (even parity), 1 stop bit

Table 7 - Communication settings for the front port

The inactivity timer for the front port is set at 15 minutes. This controls how long the relay will maintain its level of password access on the front port. If there is no communication using the front port for 15 minutes, any password access level that has been enabled is cancelled.

8.1 Front Courier Port

The front EIA(RS)232 9-pin port supports the Courier protocol for one to one communication.

Note	*The front port is actually compliant to EIA(RS)574; the 9-pin version of EIA(RS)232, see www.tiaonline.org.*

The front port is designed for use during installation, and commissioning or maintenance, and is not suitable for permanent connection. Since this interface is not used to link the relay to a substation communication system, the following features of Courier are not used.

- Automatic Extraction of Event Records:
  - Courier Status byte does not support the Event flag
  - Send Event/Accept Event commands are not implemented
- Automatic Extraction of Disturbance Records:
  - Courier Status byte does not support the Disturbance flag
- Busy Response Layer:
  - Courier Status byte does not support the Busy flag, the only response to a request will be the final data
- Fixed Address:
  - The address of the front courier port is always 1, the Change Device address command is not supported.
- Fixed Baud Rate:
  - 19200 bps

Note	*Although automatic extraction of event and disturbance records is not supported, this data can be manually accessed using the front port.*

9 MICOM S1 STUDIO RELAY COMMUNICATIONS BASICS

The EIA(RS)232 front communication port is intended for use with the relay settings program MiCOM S1 Studio. This program runs on Windows^{TM} 2000, XP or Vista, and is the universal MiCOM IED Support Software used for direct access to all stored data in any MiCOM IED.

MiCOM S1 Studio provides full access to:

- MiCOM Px10, Px20, Px30, Px40, Modulex series, K series, L series relays
- MiCOM Mx20 measurements units

9.1 PC Requirements

To run MiCOM S1 Studio on a PC, the following requirements are advised:

- Minimum
  - 1 GHz processor
  - 256 MB RAM
  - Windows^{TM} 2000
  - Resolution 800 x 600 x 256 colors
  - 1 GB free hard disk space
- Recommended
  - 2 GHz processor
  - 1 GB RAM
  - Windows^{TM} XP
  - Resolution 1024 x 768
  - 5 GB free hard disk space
- Microsoft Windows^{TM} Vista
  - 2 GHz processor
  - 1 GB RAM
  - 5 GB free hard disk space
- MiCOM S1 Studio must be started with Administrator rights

9.2 Connecting to the Relay using MiCOM S1 Studio

This section is intended as a quick start guide to using MiCOM S1 Studio and assumes you have a copy installed on your PC. See the MiCOM S1 Studio program online help for more detailed information.

1. Make sure the EIA(RS)232 serial cable is properly connected between the port on the front panel of the relay and the PC.
2. To start MiCOM S1 Studio, select **Programs** > **and navigate to** > **MiCOM S1 Studio** > **MiCOM S1 Studio**.
3. Click the **Quick Connect** tab and select **Create a New System**.
4. Check the **Path to System file** is correct, then enter the name of the system in the **Name** field. If you need to add a brief description of the system, use the **Comment** field.
5. Click **OK**.
6. Select the device type.
7. Select the communications port.
8. Once connected, select the language for the settings file, the device name, then click **Finish**. The configuration is updated.
9. In the **Studio Explorer** window, select **Device** > **Supervise Device**… to control the relay directly.

9.3 Off-Line Use of MiCOM S1 Studio

MiCOM S1 Studio can also be used as an off-line tool to prepare settings, without access to the relay.

1. If creating a new system, in the Studio Explorer, select **create new** system. Then right-click the new system and select **New substation**.
2. Right-click the new substation and select **New voltage level**.
3. Then right-click the new voltage level and select **New bay**.
4. Then right-click the new bay and select **New device**.

   You can add a device at any level, whether it is a system, substation, voltage or bay.
5. Select a device type from the list, then enter the relay type. Click **Next**.
6. Enter the full model number and click **Next.**
7. Select the **Language** and **Model**, then click **Next**.
8. Enter a unique device name, then click **Finish**.
9. Right-click the **Settings** folder and select **New File**. A default file **000** is added.
10. Right-click file **000** and select click **Open**. You can then edit the settings. See the MiCOM S1 Studio program online help for more information.

SETTINGS

CHAPTER 4

Date:	02/2013
Hardware Suffix:	M
Software Version:	D0
Connection Diagrams:	10P44303 (SH 01 and 03) 10P44304 (SH 01 and 03) 10P44305 (SH 01 and 03) 10P44306 (SH 01 and 03)
	10P44600 10P44601 (SH 1 to 2) 10P44602 (SH 1 to 2) 10P44603 (SH 1 to 2)

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1 INTRODUCTION TO SETTINGS

The relay must be configured to the system and application using appropriate settings. The sequence in which the settings are listed and described in this chapter will be the protection setting, control and configuration settings and the disturbance recorder settings (see section P44y/EN GS for the detailed relay menu map). The relay is supplied with a factory-set configuration of default settings.

2 RELAY SETTINGS CONFIGURATION

The relay is a multi-function device that supports numerous different protection, control and communication features. To simplify the setting of the relay, there is a configuration settings column which can be used to enable or disable many of the functions of the relay. The settings associated with any function that is disabled are made invisible; i.e. they are not shown in the menu. To disable a function, change the relevant cell in the '**Configuration**' column from '**Enabled'** to '**Disabled**'.

The configuration column controls which of the four protection settings groups is selected as active through the '**Active settings**' cell. A protection setting group can also be disabled in the configuration column, provided it is not the present active group. Similarly, a disabled setting group cannot be set as the active group.

The column also allows all of the setting values in one group of protection settings to be copied to another group.

To do this firstly set the '**Copy from**' cell to the protection setting group to be copied, and then set the '**copy to**' cell to the protection group where the copy is to be placed. The copied settings are initially placed in the temporary scratchpad, and will only be used by the relay following confirmation.

Menu Text	Default Setting	Available Settings
Restore Defaults	No Operation	No Operation All Settings Setting Group 1 Setting Group 2 Setting Group 3 Setting Group 4
Setting to restore a setting group to factory default settings. To restore the default values to the settings in any Group settings, set the 'restore defaults' cell to the relevant Group number. Alternatively it is possible to set the 'restore defaults' cell to 'all settings' to restore the default values to all of the IEDs settings, not just the Group settings. The default settings will initially be placed in the scratchpad and will only be used by the relay after they have been confirmed by the user. *Note* *Restoring defaults to all settings includes the rear communication port settings, which may result in communication via the rear port being disrupted if the new (default) settings do not match those of the master station.*		
Setting Group	Select via Menu	Select via Menu Select via Optos
Allows setting group changes to be initiated via Opto Input or via Menu.		
Active Settings	Group 1	Group 1, Group 2, Group 3, Group 4
Selects the active setting group.		
Save Changes	No Operation	No Operation, Save, Abort
Saves all relay settings.		
Copy from	Group 1	Group 1, 2, 3 or 4
Allows displayed settings to be copied from a selected setting group.		
Copy to	No Operation	No Operation Group 1, 2, 3 or 4
Allows displayed settings to be copied to a selected setting group (ready to paste).		
Setting Group 1	Enabled	Enabled or Disabled
If the setting group is disabled from the configuration, then all associated settings and signals are hidden, with the exception of this setting (paste).		
Setting Group 2 (as above)	Disabled	Enabled or Disabled

Menu Text	Default Setting	Available Settings
Setting Group 3 (as above)	Disabled	Enabled or Disabled
Setting Group 4 (as above)	Disabled	Enabled or Disabled
Distance	Enabled	Enabled or Disabled
To enable (activate) or disable (turn off) the Distance Protection: ANSI 21P/21G.		
Directional E/F	Enabled	Enabled or Disabled
To enable (activate) or disable (turn off) the Directional Earth Fault (DEF) Protection used in a pilot aided scheme: ANSI 67N. This protection is independent from back up Earth Fault protection described below.		
Overcurrent	Enabled	Enabled or Disabled
To enable (activate) or disable (turn off) the Phase Overcurrent Protection function. I> stages: ANSI 50/51/67P.		
Neg. Sequence O/C	Disabled	Enabled or Disabled
To enable (activate) or disable (turn off) the Negative Sequence Overcurrent Protection function. I2> stages: ANSI 46/67.		
Broken Conductor	Disabled	Enabled or Disabled
To enable (activate) or disable (turn off) the Broken Conductor function. I2/I1> stage: ANSI 46BC.		
Earth Fault	Disabled	Enabled or Disabled
To enable (activate) or disable (turn off) the back up Earth Fault Protection function. IN >stages: ANSI 50/51/67N.		
SEF/REF PROT’N	Disabled	Enabled or Disabled
To enable (activate) or disable (turn off) the Sensitive Earth Fault / Restricted Earth Fault Protection function. ISEF >stages: ANSI 50/51/67N. IREF>stage: ANSI 64.		
Residual O/V NVD	Disabled	Enabled or Disabled
To enable (activate) or disable (turn off) the Residual Overvoltage Protection function. VN>stages: ANSI 59N.		
Thermal Overload	Disabled	Enabled or Disabled
To enable (activate) or disable (turn off) the Thermal Overload Protection function. ANSI 49.		
PowerSwing Block	Enabled	Enabled or Disabled
To enable (activate) or disable (turn off) the power swing blocking/out of step: ANSI 68.		
Volt Protection	Disabled	Enabled or Disabled
To enable (activate) or disable (turn off) the Voltage Protection (under/overvoltage) function. V<, V> stages: ANSI 27/59.		
Freq Protection	Disabled	Enabled or Disabled
To enable (activate) or disable (turn off) the Frequency Protection function.		
df/dt Protection	Disabled	Enabled or Disabled
To enable (activate) or disable (turn off) the Rate-of-Change of Frequency Protection function.		
CB Fail	Disabled	Enabled or Disabled
To enable (activate) or disable (turn off) the Circuit Breaker Fail Protection function. ANSI 50BF.		
Supervision	Enabled	Enabled or Disabled
To enable (activate) or disable (turn off) the Supervision (VTS & CTS) functions. ANSI VTS/CTS.		
System Checks	Disabled	Enabled or Disabled
To enable (activate) or disable (turn off) the System Checks (Check Sync. and Voltage Monitor) function: ANSI 25.		
Auto-reclose	Disabled	Enabled or Disabled
To enable (activate) or disable (turn off) the Auto-reclose function. ANSI 79.		
Input Labels	Visible	Invisible or Visible

Menu Text	Default Setting	Available Settings
Sets the Input Labels menu visible further on in the relay settings menu.		
Output Labels	Visible	Invisible or Visible
Sets the Output Labels menu visible further on in the relay settings menu.		
CT & VT Ratios	Visible	Invisible or Visible
Sets the Current & Voltage Transformer Ratios menu visible further on in the relay settings menu.		
Record Control	Invisible	Invisible or Visible
Sets the Record Control menu visible further on in the relay settings menu.		
Disturb. Recorder	Invisible	Invisible or Visible
Sets the Disturbance Recorder menu visible further on in the relay settings menu.		
Measure't. Set-up	Invisible	Invisible or Visible
Sets the Measurement Setup menu visible further on in the relay settings menu.		
Comms. Settings	Visible	Invisible or Visible
Sets the Communications Settings menu visible further on in the relay settings menu. These are the settings associated with the 2nd rear communications ports.		
Commission Tests	Visible	Invisible or Visible
Sets the Commissioning Tests menu visible further on in the relay settings menu.		
Setting Values	Primary	Primary or Secondary
This affects all protection settings that are dependent upon CT and VT ratios. All subsequent settings input must be based in terms of this reference.		
Control Inputs	Visible	Invisible or Visible
Activates the Control Input status and operation menu further on in the relay setting menu.		
Ctrl I/P Config.	Visible	Invisible or Visible
Sets the Control Input Configuration menu visible further on in the relay setting menu.		
Ctrl I/P Labels	Visible	Invisible or Visible
Sets the Control Input Labels menu visible further on in the relay setting menu.		
Direct Access	Enabled	Enabled/Disabled/Hotkey only/CB Cntrl. only
Defines what CB control direct access is allowed. Enabled implies control via menu, hotkeys etc.		
InterMiCOM	Disabled	Enabled or Disabled
To enable (activate) or disable (turn off) EIA (RS) 232 InterMiCOM (integrated teleprotection).		
InterMiCOM^{64} Fiber	Disabled	Enabled or Disabled
To enable (activate) or disable (turn off) InterMiCOM^{64} (integrated 56/64kbit/s teleprotection).		
Function Key	Visible	Invisible or Visible
Sets the Function Key menu visible further on in the relay setting menu.		
RP1 Read Only	Disabled	Disabled/Enabled
To enable (activate) or disable (turn off) Read Only Mode of Rear Port 1.		
RP2 Read Only	Disabled	Disabled/Enabled
To enable (activate) or disable (turn off) Read Only Mode of Rear Port 2.		
NIC Read Only	Disabled	Disabled/Enabled
To enable (activate) or disable (turn off) Read Only Mode of Network Interface Card.		
LCD Contrast	11	0…31
Sets the LCD contrast.		

Table 1 - Relay settings

2.1 Default Settings Restore

To restore the default values to the settings in any protection settings group, set the **restore defaults** cell to the relevant group number. Alternatively it is possible to set the **restore defaults** cell to **all settings** to restore the default values to all of the relays settings, not just the protection groups settings. The default settings will initially be placed in the scratchpad and will only be used by the relay after they have been confirmed.

Note	*Restoring defaults to all settings includes the rear communication port settings, which may result in communication via the rear port being disrupted if the new (default) settings do not match those of the master station.*

3 PROTECTION GROUP SETTINGS

The protection settings include all the following items that become active once enabled in the configuration column of the relay menu database:

- Protection element settings
- Programmable Scheme Logic (PSL) that also includes InterMiCOM signals mapping
- Protection schemes
- Auto-reclose and check synchronization settings
- Fault locator settings.

There are four groups of protection settings, with each group containing the same setting cells. One group of protection settings is selected as the active group, and is used by the protection elements. The settings for group 1 are shown. The settings are discussed in the same order in which they are displayed in the menu.

3.1 Line Parameters

The column **GROUP x LINE PARAMETERS** is used to enter the characteristics of the protected line or cable. These settings are used by the fault locator as the base data for input to the distance to fault algorithm, and also as the reference for all distance zones when the Distance set up is preferred in the **Simple** setting mode. It also accommodates the system phase rotation (phase sequence) and defines the single or three pole tripping mode.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Line Length (km)	100	0.01	1,000	0.01
Setting of the protected line/cable length is in km. This setting is available if the MEASURE’T SETUP column is selected as Visible in the CONFIGURATION column, and if Distance unit in the MEASURE’T SETUP column is selected as kilometers.				
Line Length (miles)	62.10	0.005	621	0.005/0.01
Setting of the protected line/cable length in miles. This setting is available if MEASURE’T SETUP column is selected as Visible in the CONFIGURATION column and if Distance unit in the MEASURE’T SETUP column is selected as miles. Dual step size is provided, for cables/short lines up to 10 miles the step size is 0.005 miles, 0.01 miles otherwise.				
Line Impedance	10/In Ω	0.05/In Ω	500Ω ÷ (In x percentage reach setting of furthest reaching zone)	0.01/In Ω
Setting for protected line/cable positive sequence impedance in either primary or secondary terms, depending on the Setting Values reference chosen in the CONFIGURATION column. The set value is used for Fault locator, and for all distance zone reaches calculation if Simple setting mode under GROUP x LINE PARAMETERS is selected.				
Line Angle	70°	20°	90°	1°
Setting of the line angle (line positive sequence impedance angle).				
kZN Residual Comp	1	0	10	0.01
Setting of the residual compensation factor magnitude, used to extend the ground loop reach by a multiplication factor of (1+ kZN), is calculated as ratio: $\lvert kZN \rvert = (Z_0 – Z_1)/3Z_1$ where, Z_1 = positive sequence impedance for the protected line or cable. Z_0 = zero sequence impedance for the protected line or cable.				

<table>
<tr><th>Menu Text</th><th>Default Setting</th><th colspan="2">Setting Range</th><th>Step Size</th></tr>
<tr><th></th><th></th><th>Min.</th><th>Max.</th><th></th></tr>
<tr><td>kZN Residual Angle</td><td>0°</td><td>-180°</td><td>90°</td><td>1°</td></tr>
<tr><td colspan="5">Setting of the residual compensation factor angle (in degrees) is calculated as:
$\angle kZN = \angle (Z_0 - Z_1)/3Z_1$
where,
Z_1 = positive sequence impedance for the protected line or cable.
Z_0 = zero sequence impedance for the protected line or cable.</td></tr>
<tr><td>Mutual Comp</td><td>Disabled</td><td colspan="3">Enabled or Disabled</td></tr>
<tr><td colspan="5">To enable (activate) or disable (turn off) the Mutual compensation replica used in both, Distance and Fault locator ground fault loops.</td></tr>
<tr><td>kZm Mutual Set</td><td>1</td><td colspan="2">0</td><td>10</td></tr>
<tr><td colspan="5">Setting of the mutual compensation factor kZm magnitude is calculated as a ratio:
$|kZm| = ZM0/3Z1$
where,
ZM0 = zero sequence mutual impedance for the protected line or cable.
Z1 = positive sequence impedance for the protected line or cable.
Setting kZm is visible if Mutual Comp is enabled.</td></tr>
<tr><td>kZm Mutual Angle</td><td>0°</td><td>-180°</td><td>90°</td><td>1°</td></tr>
<tr><td colspan="5">Setting of the mutual compensation angle (in degrees) is calculated as:
$\angle kZm = \angle ZM_0/3Z_1$
Angle setting ∠kZm is visible if Mutual Comp is enabled.</td></tr>
<tr><td>Mutual Cut-off</td><td>0</td><td colspan="2">2</td><td>0.01</td></tr>
<tr><td colspan="5">*Only in models with Distance option*. Setting used to eliminate the mutual compensation replica in case when the ratio of neutral current of the parallel line to the neutral current of the protective line (I_{MUTUAL}/IN) exceeds the setting. This setting is visible only if Mutual Comp is enabled.</td></tr>
<tr><td>Phase Sequence</td><td>Standard ABC</td><td colspan="2">Standard ABC,
Reverse ACB</td><td>Phase Rotation</td></tr>
<tr><td colspan="5">This setting is used to select whether the 3 phase quantities (V and I) are rotating in the standard ABC sequence, or whether the rotation is in reverse ACB order. The appropriate selection is required to ensure that all derived sequence components and faulted phase flagging/targeting are correct.</td></tr>
<tr><td>CB1Tripping Mode</td><td>3 Pole</td><td colspan="2">3 pole, 1 and 3 pole</td><td>Trip Mode</td></tr>
<tr><td colspan="5">This setting is used to select the tripping mode. The selection 1 and 3 pole allows single pole tripping for single phase to ground faults, whilst selection 3 pole converts any trip command(s) to three pole tripping.</td></tr>
<tr><td>CB2Tripping Mode</td><td>3 Pole</td><td colspan="2">3 pole, 1 and 3 pole</td><td>Trip Mode</td></tr>
<tr><td colspan="5">This setting is used to select the tripping mode. The selection 1 and 3 pole allows single pole tripping for single phase to ground faults, whilst selection 3 pole converts any trip command(s) to three pole tripping.</td></tr>
<tr><td>Line Charging Y</td><td>2.00mS</td><td>0.00mS</td><td>10.00mS</td><td>0.1mS</td></tr>
<tr><td colspan="5">Setting for protected lines’ total susceptance in either primary or secondary terms, depending on the Setting Values reference chosen in the CONFIGURATION column. The set value is used to calculate the compensated overvoltage if V1>1 Cmp Funct setting is enabled under GROUP x VOLT PROTECTION.</td></tr>
</table>

Table 2 - Line parameters

3.2 Distance Setup

The column **GROUP x DISTANCE SETUP** is used to:

- Select the distance setting mode (simple or advanced)
- Select the operating characteristic (Mho or Quad) for phase and ground measuring loops independently
- Enable or disable each phase and ground zone independently
- Define the reach (in Ohms) for each phase and ground zone independently by simply setting the percentage required reach with reference to the line impedance (taken as the 100% reference basis)
- Other settings related to application of the **Basic** distance scheme

Menu Text	Default Setting	Setting Range		Step Size
		Min.	**Max.**	
Setting Mode	Simple	Simple or Advanced		Setting Mode
Setting to select setting mode for Distance protection, depending on type of application and user preferences. ‘Simple’ mode: Simple setting mode is the default setting mode, suitable for the majority of applications. Instead of entering distance zone impedance reaches in ohms, zone settings are simply entered in terms of percentage of the protected line data specified in the GROUP x LINE PARAMETERS/Line Impedance setting. The setting assumes that the residual compensation factor is equal for all zones. The relay auto calculates the required reaches from the percentages. The calculated zone reaches are available for viewing but a user can not alter/change the value as long as Simple mode setting remains active. Advanced setting mode: Advanced setting mode allows individual distance ohmic reaches and residual compensation factors to be entered for each zone. When Advanced mode is selected, all percentage settings that are associated to ‘Simple’ setting mode in the column GROUP x DISTANCE SETUP will be hidden and the Distance zone settings need to be entered for each zone in the GROUP x DIST. ELEMENTS column.				
PHASE DISTANCE				
Phase chars.	Mho	Disabled or Mho or Quad		21P char.
Setting to disable (turn off) phase distance protection or to set Mho or Quad operating characteristic: ANSI 21P. The chosen setting is applicable to all phase distance zones.				
Quad Resistance	Proportional	Common or Proportional		
Setting to define the mode of resistive reach coverage. If Common mode is selected, all phase distance zones will have the equal resistive coverage. If Proportional mode is selected, the zones will have resistive coverage according to the % reach set for the zone, multiplied by the Fault Resistance R_{PH} setting. This setting is visible only when Simple setting mode and quad characteristic are set.				
Fault Resistance	10/In Ω	0.1/In Ω	500/In Ω	0.01/In Ω
Setting used to specify the fault arc resistance that can be detected for faults between phases. The set value determines the right hand side of the quadrilaterals. This setting is visible only when Simple setting mode and quad characteristic are set.				
Z1 Ph Status	Enabled	Enabled or Disabled		
To enable (activate) or disable (turn off) Z1 for phase faults. This setting is invisible if Phase Char. is disabled.				
Z1 Phase Reach	80%	10%	1000%	10%
Setting entry as percentage of the line impedance that sets Zone 1 reach in ohms.				
Z2 Ph Status	Enabled	Enabled or Disabled or Enabled on CH Fail		
As per Z1, but applicable to Zone 2.				
Z2 Phase Reach	120%	10%	1000%	10%
Setting entry as percentage of the line impedance that sets Zone 2 reach in ohms.				
Z3 Ph Status	Enabled	Enabled or Disabled		

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
As per Z1, but applicable to Zone 3.				
Z3 Phase Reach	250%	10%	1000%	10%
Setting entry as percentage of the line impedance that sets Zone 3 forward reach in ohms.				
Z3 Ph Offset	Enabled	Enabled or Disabled		
To enable (activate) or disable (turn off) Zone 3 offset reach for phase faults. By default, Z3 Mho phase characteristic is offset (partly reverse directional), thus not memory/cross polarized. If Z3 Gnd Offset is disabled, Z3 Mho characteristic becomes memory/cross polarized like all other zones.				
Z3 Rev Reach	10%	10%	1000%	1%
Setting entry as percentage of the line impedance that sets Zone 3 reverse reach in ohms.				
ZP Ph Status	Enabled	Enabled or Disabled		
As per Z1, but applicable to Zone P.				
ZP Ph Dir.	Forward	Forward/ Reverse		
To directionalize Zone P forward or reverse.				
ZP Phase Reach	200%	10%	1000%	10%
Setting entry as percentage of the line impedance that sets Zone P forward or reverse reach in ohms.				
Z4 Ph Status	Enabled	Enabled or Disabled or Enabled on CH Fail		
As per Z1, but applicable to Zone 4.				
Z4 Phase Reach	150%	10%	1000%	10%
Setting entry as percentage of the line impedance that sets reverse Zone 4 reach in ohms.				
GROUND DISTANCE				
Ground Chars.	Mho	Disabled or Mho or Quad		21G char.
Setting to disable (turn off) ground distance protection or to set Mho or Quad operating characteristic: ANSI 21G. The chosen setting is applicable to all ground distance zones.				
Quad Resistance	Proportional	Common or Proportional		
Setting to define the mode of resistive reach coverage. If Common mode is selected, all ground distance zones will have the equal resistive coverage. If Proportional mode is selected, the zones will have resistive coverage according to the % reach set for the zone, multiplied by the Fault Resistance R_G setting. This setting is visible only when Simple setting mode and quad characteristic are set.				
Fault Resistance	10/In Ω	0.1/In Ω	500/In Ω	0.01/In Ω
Setting used to specify the fault arc resistance that can be detected for faults phase - ground. The set value determines the right hand side of the quadrilaterals. This setting is visible only when Simple setting mode and quad characteristic are set.				
Z1 Gnd Status	Enabled	Enabled or Disabled		
To enable (activate) or disable (turn off) Zone 1 for ground faults. This setting is invisible if Ground Char. is disabled.				
Z1 Ground Reach	80%	10%	1000%	10%
Setting entry as percentage of the line impedance that sets Zone 1 reach in ohms.				
Z2 Gnd Status	Enabled	Enabled or Disabled		
As per Z1, but applicable to Zone 2.				
Z2 Ground Reach	120%	10%	1000%	10%
Setting entry as percentage of the line impedance that sets Zone 2 reach in ohms.				
Z3 Gnd Status	Enabled	Enabled or Disabled		
As per Z1, but applicable to Zone 3.				
Z3 Ground Reach	250%	10%	1000%	10%
Setting entry as percentage of the line impedance that sets Zone 3 forward reach in ohms.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Z3 Gnd Offset	Enabled	Enabled or Disabled or Enabled on CH Fail		
To enable (activate) or disable (turn off) Zone 3 offset reach for ground faults. By default, Z3 Mho ground characteristic is offset (partly reverse directional), thus not memory/cross polarized. If Z3 Gnd Offset is disabled, Z3 Mho characteristic becomes memory/cross polarized like all other zones.				
Z3 Rev Reach	10%	10%	1000%	1%
Setting entry as percentage of the line impedance that sets Zone 3 reverse reach in ohms.				
ZP Gnd Status	Enabled	Enabled or Disabled		
As per Z1, but applicable to Zone P.				
ZP Gnd Dir.	Forward	Forward/ Reverse		
To directionalize ZP forward or reverse.				
ZP Ground Reach	200%	10%	1000%	10%
Setting entry as percentage of the line impedance that sets Zone P forward or reverse reach in ohms.				
Z4 Gnd Status	Enabled	Enabled or Disabled		
As per Z1, but applicable to Zone 4.				
Z4 Ground Reach	150%	10%	1000%	10%
Setting entry as percentage of the line impedance that sets reverse Zone 4 reach in ohms.				
Digital Filter	Standard	Standard or Special Application		
Setting to enable (activate) Standard or Special Application filters. Standard filters are the default setting and should be applied in the majority of applications. It is only the case when the fault currents and voltages may become very distorted by non-fundamental harmonics that extra filtering is necessary to avoid transient over-reach. In such system conditions the Special Applications setting should be applied.				
CVT Filters	Disabled	Disabled, Passive or Active		
Setting that accommodates the type of voltage transformer being used to prevent transient over-reach and preserve sub-cycle operating time whenever possible. In case of conventional wound VTs, the transients due to voltage collapse during faults are very small and no extra filtering is required, therefore the setting should be Disabled as per default. For a CVT with active Ferro resonance damping, the voltage distortions may be severe and risk transient over-reach. For that reason, the CVT Filters should be set to Active. Trip times increase proportionally (subcycle up to SIR = 2, gradually lengthening for SIR up to 30). For a CVT with passive Ferro resonance damping, the voltage distortions are generally small up to SIR of 30. For such applications, CVT Filters should be set Passive. The relay calculates the SIR and will take marginally longer to trip if the infeed is weak (exceeds the relay's SIR setting).				
SIR Setting	30	5	60	1
Setting that determines when extra filtering will be applied. If on fault inception the calculated SIR exceeds the SIR Setting the relay will marginally slow down, as otherwise there would be a risk of over-reach. This setting is visible only when CVT Filters is set to Passive.				
Load Blinder	Disabled	Disabled or Enabled		
Setting used to activate (enable) or turn off (disable) load blinders. Load blinders, when enabled, have two main purposes: to prevent tripping due to load encroachment under heavy load condition and detect very slow moving power swings.				
Z< Blinder Imp	15/In Ω	0.1/In Ω	500/In Ω	0.01/In Ω
Setting of radius of under-impedance circle.				
Load B/Angle	45°	15°	65°	1°
Angle setting for the two blinder lines boundary with the gradient of the rise or fall with respect to the resistive axis.				
Load Blinder V<	15V	1V	70V	0.5V
Load blinder phase to ground under-voltage setting that overrides the blinder if the measured voltage in the affected phase falls below setting. Also overrides blinding of phase-phase loops where the phase-phase voltage falls below √3 x (V< setting).				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Dist. Polarizing	1	0.2	5	0.1
The setting defines the composition of polarizing voltage as a mixture of Self and Memory polarizing voltage. Self polarized voltage is fixed to 1pu and could be mixed with Memory polarizing voltage ranging from 0.2pu up to 5pu. The default setting of 1 means that half of the polarizing voltage is made up from Self and the other half from clean Memory voltage. Adding more Memory voltage will enhance the resistive coverage of Mho characteristics, whose expansion is defined as: Mho expansion = [(Dist. Polarizing)/ (Dist. Polarizing + 1)] x Zs Where Zs is the source impedance.				
DELTA DIRECTION				
Delta Status	Enabled	Disabled or Enabled		
Setting used to enable or disable Delta Direction (∆I/∆V). To enable or disable the delta direction decision used by distance and delta directional comparison elements. If disabled, any directionalized distance zones use conventional cross and memory polarized directional lines				
AidedDeltaStatus	Phase + Ground	Disabled, Phase only, Ground only or Phase + Ground		
This setting is only used for channel aided schemes, and is used to select which types of fault Delta Directional Comparison protection to apply. When this setting is disabled, Delta V Fwd, Delta V Rev, Delta I Fwd and Delta I Rev are invisible. This setting is invisible if the Delta Status setting is disabled.				
Delta Char Angle	60°	0°	90°	1°
Setting for the relay characteristic angle used for the delta directional decision.				
Delta V Fwd	5V	1V	30V	0.1V
Setting for the minimum delta voltage change to permit the directional forward decision.				
Delta V Rev	4V	0.5V	30V	0.1V
Setting for the minimum delta voltage change to permit the directional reverse decision.				
Delta I Fwd	0.1 x In	0.1 x In	10 x In	0.01 x In
Setting for the minimum delta current change to permit the directional forward decision.				
Delta I Rev	0.08 x In	0.05 x In	10 x In	0.01 x In
Setting for the minimum delta current change to permit the directional reverse decision.				

Table 3 - Distance setup

3.3 Distance Elements

The column **GROUP x DISTANCE ELEMENTS** is used to individually set reaches, line angles, neutral compensation factors, minimum current operating levels and line tilting for resistive phase faults for each zone if the setting mode is set to **Advanced**. In **Simple** setting mode, **Distance Elements** setting can be **viewed**, but not edited here.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
PHASE DISTANCE				
Z1 Ph. Reach	8/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z1 reach.				
Z1 Ph. Angle	70°	20°	90°	1°
Setting of line angle for zone 1.				
R1 Ph. Resistive	8/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z1 resistive reach. This setting is only visible if Quad is selected.				
Z1 Tilt Top Line	-3°	-30°	30°	1°
Setting of Z1 top reactance line gradient to avoid over-reach for resistive phase faults under heavy load. Minus angle tilts the reactance line downwards.				
Z1 Sensit. Iph>1	0.075 x In	0.05 x In	2 x In	0.01 x In
Current sensitivity setting for Z1 that must be exceeded in faulted phases if Z1 is to operate.				
Z2 Ph. Reach	15/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z2 reach.				
Z2 Ph. Angle	70°	20°	90°	1°
Setting of line angle for zone 2.				
R2 Ph. Resistive	15/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z2 resistive reach.				
Z2 Tilt Top Line	-3°	-30°	30°	1°
Setting of Z2 top reactance line gradient.				
Z2 Sensit. Iph>2	0.075 x In	0.05 x In	2 x In	0.01 x In
Zone 2 current sensitivity.				
Z3 Ph. Reach	25/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z3 reach.				
Z3 Ph. Angle	70°	20°	90°	1°
Setting of line angle for zone 3.				
Z3’ Ph. Rev Reach	1/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z3 offset (reverse) reach. This setting is only visible if Z3 Offset is enabled in GROUP x DISTANCE SETUP.				
R3 Ph. Res Fwd.	25/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z3 resistive reach that defines Quad’s right hand line.				
R3’ Ph. Res Rev.	1/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z3 resistive reach that defines Quad’s left hand line. This is settable only if Phase Chars. is Quad and Z3 offset is enabled otherwise is fixed to 25% of the right hand blinder.				
Z3 Tilt Top Line	-3°	-30°	30°	1°
Setting of Z3 top reactance line gradient.				
Z3 Sensit. Iph>3	0.050 x In	0.05 x In	2 x In	0.01 x In
Zone 3 current sensitivity.				
ZP Ph. Reach	20/In Ω	0.1/In Ω	500/In Ω	0.01/In Ω

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Setting for ZP reach.				
ZP Ph. Angle	70°	20°	90°	1°
Setting of line angle for zone P.				
RP Ph. Resistive	20/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for ZP resistive reach.				
ZP Tilt Top Line	-3°	-30°	30°	1°
Setting of ZP top reactance line gradient.				
ZP Sensit. Iph>P	0.05 x In	0.05 x In	2 x In	0.01 x In
Zone P current sensitivity.				
Z4 Ph. Reach	15/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z4 reach. This is a common setting for Z4 time delayed and Z4 high speed elements used in blocking schemes and for current reversal guard.				
Z4 Ph. Angle	70°	20°	90°	1°
Setting of line angle for zone 4.				
R4 Ph. Resistive	15/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for ZP resistive reach.				
Z4 Tilt Top Line	-3°	-30°	30°	1°
Setting of Z4 top reactance line gradient.				
Z4 Sensit. Iph>4	0.05 x In	0.05 x In	2 x In	0.01 x In
Zone P current sensitivity.				
GROUND DISTANCE				
Z1 Gnd. Reach	8/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z1 reach.				
Z1 Gnd. Angle	70°	20°	90°	1°
Setting of line angle (positive sequence) for zone 1.				
Z1 Dynamic Tilt	Enabled	Disabled or Enabled		
Setting that enables or disables zone 1 top reactance line dynamic tilting. If set enabled, the top line angle will be automatically shifted by the angle difference between the fault current and negative sequence current, starting from the Z1 Tilt top line angle setting – see the next cell. The zone 1 is allowed only to tilt down. If Dynamic tilting is disabled, the top line will be shifted by the Z1 Tilt top line setting (Predetermined tilting by fixed angle). This setting is visible only when ground characteristic is set to Quad.				
Z1 Tilt top line	-3°	-30°	30°	1°
Setting of the zone 1 tilt angle. Minus angle tilts the reactance line downwards This setting is visible only when the above setting is visible.				
kZN1 Res. Comp.	1	0	10	0.001
Setting of Z1 residual compensation magnitude.				
kZN1 Res. Angle	0	-180°	90°	1°
Setting of Z1 residual compensation angle.				
R1 Gnd. Resistive	8/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z1 ground resistive reach. This setting is only visible if Quad is selected.				
Z1 Sensit. Ignd>1	0.075 x In	0.05 x In	2 x In	0.01 x In
Current sensitivity setting for Z1 that must be exceeded in faulted phase and the neutral if Z1 is to operate.				
Z2 Gnd. Reach	15/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z2 reach.				
Z2 Gnd. Angle	70°	20°	90°	1°

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Setting of line angle (positive sequence) for zone 2.				
Z2 Dynamic Tilt	Enabled	Disabled or Enabled		
Setting that enables or disables zone 2 top reactance line dynamic tilting. If set enabled, the top line angle will be automatically shifted by the angle difference between the fault current and negative sequence current, starting from the Z2 Tilt top line angle setting – see the next cell. The zone 2, as over-reaching zone, is allowed only to tilt up. If Dynamic tilting is disabled, the top line will be shifted by the Z2 Tilt top line setting (Predetermined tilting by fixed angle). This setting is visible only when ground characteristic is set to Quad.				
Z2 Tilt top line	-3°	-30°	30°	1°
Setting of the zone 2 tilt angle. Minus angle tilts the reactance line downwards This setting is visible only when the above setting is visible.				
kZN2 Res. Comp.	1	0	10	0.001
Setting of Z2 residual compensation magnitude.				
kZN2 Res. Angle	0	-180°	90°	1°
Setting of Z2 residual compensation angle.				
R2 Gnd. Resistive	15/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z2 ground resistive reach.				
Z2 Sensit. Ignd>2	0.075 x In	0.05 x In	2 x In	0.01 x In
Zone 2 current sensitivity.				
Z3 Gnd. Reach	25/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z3 reach.				
Z3 Gnd. Angle	70°	20°	90°	1°
Setting of line angle (positive sequence) for zone 3.				
Z3' Gnd. Rev Rch	1/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z3 offset (reverse) reach. This setting is only visible if Z3 Offset is enabled in GROUP x DISTANCE SETUP.				
Z3 Dynamic Tilt.	Enabled	Disabled or Enabled		
Setting that enables or disables Z3 top reactance line dynamic tilting. If set enabled, the top line angle will be automatically shifted by the angle difference between the fault current and negative sequence current, starting from the Z3 Tilt top line angle setting – see the next cell. The ZP, as over-reaching zone, is allowed only to tilt up. If Dynamic tilting is disabled, the top line will be shifted by the ZP Tilt top line setting (Predetermined tilting by fixed angle). This setting is visible only when ground characteristic is set to Quad and Z3 offset disabled.				
Z3 Tilt top line	-3°	-30°	30°	1°
Setting of the Z3 tilt angle. Minus angle tilts the reactance line downwards This setting is visible only when the above setting is visible.				
kZN3 Res. Comp.	1	0	10	0.001
Setting of Z3 residual compensation magnitude.				
kZN3 Res. Angle	0	-180°	90°	1°
Setting of Z3 residual compensation angle.				
R3 Gnd. Res. Fwd	25/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z3 resistive reach that defines Quad's right hand line.				
R3' Gnd. Res. Rev	1/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z3 resistive reach that defines Quad's left hand line. This is settable only if Phase Chars. is Quad and Z3 offset is enabled otherwise is fixed to 25% of the right hand blinder				
Z3 Sensit. Ignd>3	0.05 x In	0.05 x In	2 x In	0.01 x In
Zone 3 current sensitivity.				
ZP Gnd. Reach	20/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for ZP reach.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
ZP Gnd. Angle	70°	20°	90°	1°
Setting of line angle (positive sequence) for zone P.				
ZP Dynamic Tilt	Enabled	Disabled or Enabled		
Setting that enables or disables ZP top reactance line dynamic tilting. If set enabled, the top line angle will be automatically shifted by the angle difference between the fault current and negative sequence current, starting from the ZP Tilt top line angle setting – see the next cell. The ZP, as over-reaching zone, is allowed only to tilt up. If Dynamic tilting is disabled, the top line will be shifted by the ZP Tilt top line setting (Predetermined tilting by fixed angle). This setting is visible only when ground characteristic is set to Quad.				
ZP Tilt top line	-3°	-30°	30°	1°
Setting of the ZP tilt angle. Minus angle tilts the reactance line downwards This setting is visible only when the above setting is visible.				
kZNP Res. Angle	0	-180°	90°	1°
Setting of ZP residual compensation angle.				
RP Gnd. Resistive	20/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for ZP ground resistive reach.				
ZP Sensit. Ignd>P	0.05 x In	0.05 x In	2 x In	0.01 x In
Zone P current sensitivity.				
Z4 Gnd. Reach	15/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z4 reach. This is a common setting for Z4 time delayed and Z4 high speed elements used in blocking schemes and for current reversal guard.				
Z4 Gnd. Angle	70°	20°	90°	1°
Setting of line angle (positive sequence) for zone 4.				
Z4 Dynamic Tilt	Enabled	Disabled or Enabled		
Setting that enables or disables Z4 top reactance line dynamic tilting. If set enabled, the top line angle will be automatically shifted by the angle difference between the fault current and negative sequence current, starting from the Z4 Tilt top line angle setting – see the next cell. The Z4, as over-reaching zone, is allowed only to tilt up. If Dynamic tilting is disabled, the top line will be shifted by the Z4 Tilt top line setting (Predetermined tilting by fixed angle). This setting is visible only when ground characteristic is set to Quad.				
Z4 Tilt top line	-3°	-30°	30°	1°
Setting of the Z4 tilt angle. Minus angle tilts the reactance line downwards This setting is visible only when the above setting is visible.				
kZN4 Res. Angle	0	-180°	90°	1°
Setting of Z4 residual compensation angle.				
R4 Gnd. Resistive	15/In Ω	0.05/In Ω	500/In Ω	0.01/In Ω
Setting for Z4 ground resistive reach.				
Z4 Sensit. Ignd>4	0.05 x In	0.05 x In	2 x In	0.01 x In
Zone 4 current sensitivity.				

Table 4 - Distance elements

3.4 Scheme Logic (Basic and Aided Scheme Logic)

The column **GROUP x SCHEME LOGIC** is used to:

- Set operating mode and associated timers for each distance zone when distance operates in the Basic scheme
- Select aided schemes via one or two available signaling channels
- Define operating zones during Trip On Close (TOC)

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
BASIC SCHEME				
Zone 1 Tripping	Phase and Ground	Disabled, Phase only, Ground only, or Phase and Ground		
Setting to select for which types of fault Zone 1 elements will be applied.				
tZ1 Ph. Delay	0s	0s	10s	0.01s
Time delay for Z1 phase element.				
tZ1 Gnd. Delay	0s	0s	10s	0.01s
Time delay for Z1 ground element.				
Zone 2 Tripping	Phase and Ground	Disabled, Phase only, Ground only, or Phase and Ground		
Setting to select for which types of fault Zone 2 elements will be applied.				
tZ2 Ph. Delay	0.2s	0s	10s	0.01s
Time delay for Z2 phase element.				
tZ2 Gnd. Delay	0.2s	0s	10s	0.01s
Time delay for Z2 ground element.				
Zone 3 Tripping	Phase and Ground	Disabled, Phase only, Ground only, or Phase and Ground		
Setting to select for which types of fault Zone 3 elements will be applied.				
tZ3 Ph. Delay	0.6s	0s	10s	0.01s
Time delay for Z3 phase element.				
tZ2 Gnd. Delay	0.6s	0s	10s	0.01s
Time delay for Z3 ground element.				
Zone P Tripping	Phase and Ground	Disabled, Phase only, Ground only, or Phase and Ground		
Setting to select for which types of fault Zone P elements will be applied.				
tZP Ph. Delay	0.4s	0s	10s	0.01s
Time delay for ZP phase element.				
tZP Gnd. Delay	0.4s	0s	10s	0.01s
Time delay for ZP ground element.				
Zone 4 Tripping	Phase and Ground	Disabled, Phase only, Ground only, or Phase and Ground		
Setting to select for which types of fault Zone 4 elements will be applied.				
tZ4 Ph. Delay	1s	0s	10s	0.01s
Time delay for Z4 phase element.				
tZ4 Gnd. Delay	1s	0s	10s	0.01s
Time delay for Z4 ground element.				
AIDED SCHEME 1				
Aid. 1 Selection	Disabled	Disabled, PUR, PUR Unblocking, POR, POR Unblocking, Blocking 1, Blocking 2, Prog. Unblocking or Programmable		

Menu Text	**Default Setting**	**Setting Range**		**Step Size**
		Min.	**Max.**	
Selection of the generic scheme type for aided channel 1. *Note* *POR is equivalent to POTT (permissive overreach transfer trip), PUR is equivalent to PUTT (permissive underreach transfer trip).*				
Aid 1 Distance	Phase and Ground	Disabled, Phase Only, Ground Only, or Phase and Ground		
Setting to select whether distance elements should key the scheme selected as per the previous setting. If set to Disabled, no distance zones interact with this aided scheme, and basic scheme tripping only applies.				
Aid. 1 Dist. Dly	0s	0s	1s	0.002s
Trip time delay for Aided 1 Distance schemes.				
Aid. 1 DEF	Enabled	Disabled or Enabled		
Setting to select whether a DEF scheme should be mapped to Aided scheme 1. (Not applicable where a Permissive Underreaching scheme selection has been made).				
Aid. 1 DEF Dly	0s	0s	1s	0.002s
Time delay for Aided 1 DEF tripping.				
Aid. 1 DEF Trip	3 Pole	1 or 3 Pole		
Setting that defines the tripping mode for Aided 1 DEF. This setting is visible only if tripping mode under GROUP x LINE PARAMETERS /Trip Mode is set to 1 and 3 pole.				
Aid. 1 Delta	Enabled	Disabled or Enabled		
Setting to select whether a Delta directional comparison scheme should be mapped to Aided scheme 1. (Not applicable where a Permissive Underreaching scheme selection has been made).				
Aid. 1 Delta Dly	0s	0s	Aid. 1 Delta Dly	0s
Time delay for Aided 1 Delta tripping.				
Aid. 1 DeltaTrip	3 Pole	1 or 3 Pole		
Setting that defines tripping mode for Aided 1 Delta. This setting is visible only if tripping mode under GROUP x LINE PARAMETERS / Trip Mode is set to 1 and 3 pole.				
tREV. Guard	0.02s	0s	0.15s	0.002s
Setting for the current reversal guard timer. Intended to keep stability on a healthy line, whilst breakers open on a faulted parallel line to clear the fault. This setting is visible only when over-reaching or Blocking schemes are selected.				
Unblocking Delay	0.05s	0s	0.1s	0.002s
Time delay after Loss of Guard until unblocking occurs. After the set delay, the relay will respond as though an aided signal has been received from the remote end. This setting is visible only when PUR Unblocking, POR Unblocking or Programmable Unblocking schemes are chosen.				
Weak Infeed	Disabled	Disabled, Echo, or Echo and Trip		
Setting that defines Aided 1 scheme operation in case of weak infeed conditions, where no protection elements detect the fault at the local end, but an aided channel has been received from the remote end. Setting Echo will allow the received signal to be returned to the remote relay, Trip will allow local end tripping after a set delay.				
WI Sngl Pole Trp	Disabled	Disabled or Enabled		
Setting that defines the Weak Infeed tripping mode. When disabled, any WI trip will be converted to a 3 phase trip.				
WI V< Thresh.	45V	10V	70V	5V
Setting of Weak Infeed level detector. If phase - ground voltage in any phase drops below the threshold and with insufficient phase current for the protection to operate, the end is declared as a weak infeed terminal.				
WI Trip Delay	0.06s	0s	1s	0.002s
Setting for the weak infeed trip time delay.				
Custom Send Mask	0000000001	Bit 0 = Z1 Gnd, Bit 1 = Z2 Gnd, Bit 2 = Z4 Gnd, Bit 3 = Z1 Ph, Bit 4 = Z2 Ph, Bit 5 = Z4 Ph, Bit 6 = DEF Fwd, Bit 7 = DEF Rev, Bit		

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Logic Settings that determine the element or group of elements that are sending a permissive signal to the other line end. For the signal to be sent, the element must operate and a corresponding bit in the matrix must be set to “1” (High). The above mapping is part of a custom made Aided 1 scheme, and unlike all other schemes that are factory tested, the customer must take the responsibility for testing and the operation of the scheme. This setting is visible only if a Programmable or Prog. Unblocking scheme is selected.				
Custom Time PU	0s	0s	1s	0.002s
Pick up time delay of DDB signal Aid1 CustomT in, available in the PSL logic. Once the time delay elapses, the DDB signal Aid1 CustomT out will become high.				
Custom Time DO	0s	0s	1s	0.002s
Drop off time delay of DDB signal Aid1 CustomT in. Once the time delay elapses, the DDB signal Aid1 CustomT out will become low. *Note The timer is a combined hard coded PU/DO timer for Custom Aided scheme 1.*				
AIDED SCHEME 2				
All the settings are similar to AIDED SCHEME 1 above. Elements are mapped to the second scheme when they are wished to run independent of Aided Scheme 1.				
Trip On Close				
SOTF Status	Enabled Pole Dead	Disabled, Enabled Pole Dead, Enabled ExtPulse, En Pdead + Pulse		
Setting that enables note (turns on) or disables (turns off) a special protection logic which can apply upon line energization. SOTF = Switch on to Fault. *Note SOTF can be enabled in three different manners:* Enabled Pole Dead. By using pole dead logic detection logic Enabled ExtPulse. By using an external pulse En Pdead + Pulse. By using both				
	110s	0.2s	1000s	0.2s
The SOTF Delay is a pick up time delay that starts after opening all 3 poles of a CB. If the CB is then closed after the set time delay has expired, SOTF protection will be active. SOTF provides enhanced protection for manual closure of the breaker (not for auto-reclosure). This setting is visible only if Pole Dead or Pdead + Pulse are selected to enable SOTF.				
SOTF Tripping	000001	Bit 0 = Zone 1, Bit 1 = Zone 2, Bit 2 = Zone 3, Bit 3 = Zone P, Bit 4 = Zone 4, Bit 5 = Current No Volt		
Logic Settings that determine the Distance zones that are allowed to operate instantaneously upon line energization. If, for example, Bit 1 is set to 1 (High), Z2 will operate without waiting for the usual tZ2 time delay should a fault lie within Z2 upon CB closure. It also allows a user to map Currents No Volt option for fast fault clearance upon line energization. SOTF tripping is 3 phase and auto-reclose will be blocked.				
TOR Status	Enabled	Disabled or Enabled		
Setting that enables (turns on) or disables (turns off) special protection following auto-reclosure. When set Enabled, TOR will be activated after the TOC Delay has expired, ready for application when an auto-reclose shot occurs. TOR = Trip on (auto)Reclose.				
TOR Tripping	000001	Bit 0 = Zone 1, Bit 1 = Zone 2, Bit 2 = Zone 3, Bit 3 = Zone P, Bit 4 = Zone 4, Bit 5 = Current No Volt		
Logic Settings that determine the Distance zones that are allowed to operate instantaneously upon line energization. If, for example, Bit 1 is set to “1” (High), Z2 will operate without waiting for the usual tZ2 time delay should a fault lie within Z2 upon CB closure. It also allows a user to map Currents No Volt option for fast fault clearance upon line re-closure on a permanent fault. TOR tripping is 3 phase and auto-reclose will be blocked.				
TOC Reset Delay	0.5s	0.1s	2s	0.1s

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
The TOC Reset Delay is a user settable time window during which TOC protection is available. The time window starts timing upon CB closure and it is common for SOTF and TOR protection. Once this timer expires after a successful (re)closure, all protection reverts to normal.				
TOC Delay	0.2s	0.05s	0.2s	0.01s
The TOC Delay is a user settable time delay following the CB opening after which the TOR becomes active (enabled). The time must be set in conjunction with the Dead Time setting of the Auto-reclose so that the setting must not exceed the minimum Dead Time setting since both timers start instantaneously.				
SOTF Pulse	0.5s	0.1s	10s	0.01s
The SOTF Pulse is a user settable time window during which the SOTF protection is available. This setting is visible only if ExtPulse or Pdead + Pulse are selected to enable SOTF.				
Z1 Extension				
Z1 Ext Scheme	Disabled	Disabled, Enabled, En. on Ch1 Fail, En. On Ch2 Fail, En All Ch Fail, or En. Any Ch Fail		
Setting that enables (turns on) or disables (turns off) the Zone 1 Extension scheme. When Enabled, extended Zone 1 will apply unless the Reset Zone 1 Extension DDB signal is energized. Otherwise, it is possible to enable Z1X when aided scheme channel(s) fail.				
Z1 Ext Ph	150%	100%	200%	1%
Extended Z1X phase reach as a percentage of the Z1 phase reach. (Phase resistive reach for Z1X is the same as for Zone 1).				
Z1 Ext Gnd	150%	100%	200%	1%
Extended Z1X ground reach as a percentage of Z1 ground reach. (Ground resistive reach and residual compensation for Z1X is the same as for Zone 1).				
Loss of Load				
LOL Scheme	Disabled	Disabled, Enabled, En. on Ch1 Fail, En. On Ch2 Fail, En All Ch Fail, or En. Any Ch Fail		
Setting that enables (turns on) or disables (turns off) the Loss of Load scheme. When Enabled, accelerated tripping can apply as the remote end opens (3-pole trip applications only). Otherwise, it is possible to enable Z1X when aided scheme channel(s) fail.				
LOL <I	0.5 x In	0.05 x In	1 x In	0.05 x In
LOL undercurrent detector that indicates a loss of load condition on the unfaulted phases, indicating that the remote end has just opened.				
LOL Window	0.04s	0.01s	0.1s	0.01s
Length of LOL window - the time window in which Zone 2 accelerated tripping can occur following LOL undercurrent detector operation.				

Table 5 - Scheme logic

3.5 Power Swing Blocking

The column **GROUP x POWER SWING Blk.** is used to set either blocking or indication for out of step conditions. If blocking mode is selected, a user can individually select for each zone to be either blocked or allow tripping.

The power swing detection is based on superimposed current, and is essentially **settings free**.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
PSB Status	Blocking	Blocking or Indication		
To enable (activate) Indication or Blocking mode. This setting is invisible if disabled in CONFIGURATION column. If Indication status is selected, the alarm will be issued but tripping by distance protection will be unaffected. When Blocking status is selected, the user is presented with further options as to which zones do/do not require blocking.				
Zone 1 Ph. PSB	Blocking	Blocking, Delayed Unblocking, or Allow trip		
Setting that defines the Z1 phase element operation should any swing impedance enter and remains inside the Z1 phase characteristic for more then tZ1 Ph. Delay. If Blocking is selected, the Z1 phase element operation will be disabled for the duration of the swing. If Unblocking is chosen, the Z1 phase element block will be removed after drop off timer PSB Unblocking Dly has expired, even if the swing is still present. This allows system separation when swings fail to stabilize. In Allow trip mode, the Z1 phase element is unaffected by PSB detection.				
Zone x Ph. PSB	Blocking	Blocking, Delayed Unblocking, or Allow trip		
Individual Zone setting options all as per Zone 1 Ph. (x = 2, 3, 4, P).				
Zone 1 Gnd. PSB	Blocking	Blocking, Delayed Unblocking, or Allow trip		
Setting that defines the Z1 ground element operation should any swing impedance enter and remains inside the Z1 ground characteristic for more then tZ1 Gnd. Delay. If Blocking is selected, the Z1 ground element operation will be disabled for the duration of the swing. If Unblocking is chosen, the Z1 ground element block will be removed after drop off timer PSB Unblocking Dly has expired, even if the swing is still present. This allows system separation when swings fail to stabilize. In Allow trip mode, the Z1 ground element is unaffected by PSB detection.				
Zone x Gnd. PSB	Blocking	Blocking, Delayed Unblocking, or Allow trip		
Individual Zone setting options all as per Zone 1 Gnd. (x = 2, 3, 4, P).				
PSB Unblocking	Disabled	Disabled or Enabled		
To enable (activate) or disable (turn off) the PSB Unblocking delay timer. This setting is common to all zones and it is visible if any distance zone is set to PSB Unblocking Dly. For swing durations longer than this setting, blocking can be selectively removed.				
PSB Unblock dly	2s	0.1s	10s	0.1s
Unblock timer setting - on expiry, power swing blocking can optionally be removed.				
PSB Reset Delay	0.2s	0.05s	2s	0.05s
Setting to maintain the power swing detection for a period after the delta current detection has reset. ∆I will naturally reset momentarily twice in each swing cycle, and a short setting ensures continued PSB pick-up, to ride through the gaps.				
OST Mode	Disabled	Disabled, Pred.& OST Trip, OST Trip, Pred. OST Trip		

<table>
<tr><th>Menu Text</th><th>Default Setting</th><th colspan="2">Setting Range</th><th>Step Size</th></tr>
<tr><th></th><th></th><th>Min.</th><th>Max.</th><th></th></tr>
<tr><td colspan="5">To enable (activate) or disable (turn off) Out of Step protection. This setting (and all related settings below) is invisible if PowerSwing Block is disabled in CONFIGURATION column.
If ‘OST Trip’ is selected, relay will operate after Tost time delay if the measured positive sequence impedance has passed the Z6-Z5 region slower than 25ms (@50 or 60Hz) and if the polarity of the resistive component has changed between entering and exiting zone 5.
If Predictive OST Trip is selected, relay will operate after Tost time delay if the positive sequence impedance has passed the Z6-Z5 region faster than 25ms but slower than Delta t set time.
If Predictive & OST Trip is selected, it will operate if any of two above criteria is satisfied.</td></tr>
<tr><td>Z5</td><td>30/In Ω</td><td>0.1/In Ω</td><td>500/In Ω</td><td>0.01/In Ω</td></tr>
<tr><td colspan="5">Setting for Z5 forward reactance reach.</td></tr>
<tr><td>Z6</td><td>32/In Ω</td><td>0.1/In Ω</td><td>500/In Ω</td><td>0.01/In Ω</td></tr>
<tr><td colspan="5">Setting for Z6 forward reactance reach.</td></tr>
<tr><td>Z5’</td><td>-30/In Ω</td><td>-0.1/In Ω</td><td>-500/In Ω</td><td>0.01/In Ω</td></tr>
<tr><td colspan="5">Setting for Z5 reverse reactance reach.</td></tr>
<tr><td>Z6’</td><td>-32/In Ω</td><td>-0.1/In Ω</td><td>-500/In Ω</td><td>0.01/In Ω</td></tr>
<tr><td colspan="5">Setting for Z6 reverse reactance reach.</td></tr>
<tr><td>R5</td><td>20/In Ω</td><td>0.1/In Ω</td><td>200/In Ω</td><td>0.01/In Ω</td></tr>
<tr><td colspan="5">Setting for Z5 positive resistive reach.</td></tr>
<tr><td>R6</td><td>22/In Ω</td><td>0.1/In Ω</td><td>200/In Ω</td><td>0.01/In Ω</td></tr>
<tr><td colspan="5">Setting for Z6 positive resistive reach.</td></tr>
<tr><td>R5’</td><td>-20/In Ω</td><td>-0.1/In Ω</td><td>-200/In Ω</td><td>0.01/In Ω</td></tr>
<tr><td colspan="5">Setting for Z5 negative resistive reach.</td></tr>
<tr><td>R6’</td><td>-22/In Ω</td><td>-0.1/In Ω</td><td>-200/In Ω</td><td>0.01/In Ω</td></tr>
<tr><td colspan="5">Setting for Z6 negative resistive reach.</td></tr>
<tr><td>Blinder Angle</td><td>80°</td><td>20°</td><td>90°</td><td>1°</td></tr>
<tr><td colspan="5">Setting of Blinder angle, common for both Z5 and Z6.</td></tr>
<tr><td>Delta t</td><td>0.03s</td><td>0.03s</td><td>1s</td><td>0.001s</td></tr>
<tr><td colspan="5">Time setting that is compared with the measured time between positive sequence impedance entering Z6 and entering Z5.</td></tr>
<tr><td>Tost</td><td>0s</td><td>0s</td><td>1s</td><td>0.01s</td></tr>
<tr><td colspan="5">Tripping time delay common for any OST setting option.</td></tr>
</table>

Table 6 - Power swing block

3.6 Phase Overcurrent Protection

The overcurrent protection included in the MiCOM P443/P446 provides four-stage non-directional/ directional phase segregated overcurrent protection with independent time delay characteristics. All overcurrent and directional settings apply to each phase but are independent for each of the four stages. To arrange a single pole tripping by overcurrent protection, the default PSL needs to be modified.

The first two stages of overcurrent protection have time-delayed characteristics which are selectable between Inverse Definite Minimum Time (IDMT), or Definite Time (DT). The third and fourth stages have definite time characteristics only.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
I>1 Status	Enabled	Disabled, Enabled, or Enabled VTS		
Setting that defines first stage overcurrent operating status. Depending of this setting, I>1 will be enabled permanently or in case of Voltage Transformer Supervision (fuse fail) operation.				
I>1 Function	IEC S Inverse	DT, IEC S Inverse, IEC V Inverse, IEC E inverse, UK LT Inverse IEEE M Inverse, IEEE V Inverse, IEEE E Inverse, US Inverse, US ST Inverse		
Setting for the tripping characteristic for the first stage overcurrent element.				
I>1 Directional	Non-directional	Non-directional Directional Fwd Directional Rev		
This setting determines the direction of measurement for first stage element.				
I>1 Current Set	1 x In	0.08 x In	4.0 x In	0.01 x In
Pick-up setting for first stage overcurrent element.				
I>1 Time Delay	1s	0s	100s	0.01s
Setting for the time-delay for the definite time setting if selected for first stage element. The setting is visible only when DT function is selected.				
I>1 TMS	1	0.025	1.2	0.005
Setting for the time multiplier setting to adjust the operating time of the IEC IDMT characteristic.				
I>1 Time Dial	1	0.01	100	0.01
Setting for the time multiplier setting to adjust the operating time of the IEEE/US IDMT curves. The Time Dial (TD) is a multiplier on the standard curve equation to achieve the required tripping time. The reference curve is based on TD = 1. Care: Certain manufacturers use a mid-range value of TD = 5 or 7, so it may be necessary to divide by 5 or 7 to achieve parity.				
I>1 Reset Char.	DT	DT or Inverse		N/A
Setting to determine the type of reset/release characteristic of the IEEE/US curves.				
I>1 tRESET	0s	0s	100s	0.01s
Setting that determines the reset/release time for definite time reset characteristic.				
I>2 Cells as for I>1 above				
Setting the same as for the first stage overcurrent element.				
I>3 Status	Disabled	Disabled, Enabled or Enabled VTS		
Setting that defines third stage overcurrent operating status. Depending of this setting, I>3 will be enabled permanently or in case of Voltage Transformer Supervision (fuse fail) operation.				
I>3 Directional	Non-directional	Non-directional Directional Fwd Directional Rev		N/A
This setting determines the direction of measurement for the overcurrent element.				
I>3 Current Set	10 x In	0.08 x In	32 x In	0.01 x In

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Pick-up setting for third stage overcurrent element.				
I>3 Time Delay	0s	0s	100s	0.01s
Setting for the operating time-delay for third stage overcurrent element.				
I>4 Cells as for I>3 Above				
Settings the same as the third stage overcurrrent element.				
I> Char. Angle	30°	–95°	+95°	1°
Setting for the relay characteristic angle used for the directional decision. The setting is visible only when Directional Fwd or Directional Rev is set.				
I> Blocking	00001111	Bit 0 = VTS Blocks I>1, Bit 1 = VTS Blocks I>2, Bit 2 = VTS Blocks I>3, Bit 3 = VTS Blocks I>4, Bits 5 to 7 are not used.		
Logic settings that determine whether blocking signals from VT supervision affect certain overcurrent stages. VTS Block - only affects directional overcurrent protection. With the relevant bit set to 1, operation of the Voltage Transformer Supervision (VTS) will block the stage. When set to 0, the stage will revert to Non-directional upon operation of the VTS. If I> Status is set Enabled VTS, no blocking should be selected to provide fault clearance by overcurrent protection during the VTS condition.				

Table 7 - Phase overcurrent protection

3.7 Negative Sequence Overcurrent

The negative sequence overcurrent protection included in the MiCOM P443/P446 provides four stage non-directional/ directional phase segregated negative sequence overcurrent protection with independent time delay characteristics. The first two stages of negative sequence overcurrent protection have time-delayed characteristics which are selectable between Inverse Definite Minimum Time (IDMT), or Definite Time (DT). The third and fourth stages have definite time characteristics only.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
I2>1 Status	Disabled	Disabled or Enabled		N/A
Setting to enable or disable the first stage negative sequence element.				
I2>1 Function	DT	Disabled, DT, IEC S Inverse, IEC V Inverse, IEC E Inverse, UK LT Inverse, IEEE M Inverse, IEEE V Inverse, IEEE E Inverse, US Inverse, US ST Inverse.		
Setting for the tripping characteristic for the first stage negative sequence overcurrent element.				
I2>1Direction	Non-directional	Non-directional Directional Fwd Directional Rev		N/A
This setting determines the direction of measurement for this element.				
I2>1 Current Set	0.2 x In	0.08In	4In	0.01In
Pick-up setting for the first stage negative sequence overcurrent element.				
I2>1 Time Delay	10	0s	100s	0.01s
Setting for the operating time-delay for the first stage negative sequence overcurrent element.				
I2>1 TMS	1	0.025	1.2	0.005

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Setting for the time multiplier setting to adjust the operating time of the IEC IDMT characteristic.				
I2>1 Time Dial	1	0.01	100	0.01
Setting for the time multiplier setting to adjust the operating time of the IEEE/US IDMT curves.				
I2>1 Reset Char.	DT	DT or Inverse		N/A
Setting to determine the type of reset/release characteristic of the IEEE/US curves.				
I2>1 tRESET	0	0s	100s	0.01s
Setting that determines the reset/release time for definite time reset characteristic.				
I2>2 Cells as for I2>1 Above				
I2>3 Status	Disabled	Disabled or Enabled		N/A
Setting to enable or disable the third stage negative sequence element.				
I2>3 Direction	Non-directional	Non-directional Directional Fwd Directional Rev		N/A
This setting determines the direction of measurement for this element.				
I2>3 Current Set	0.2 x In	0.08In	32In	0.01In
Pick-up setting for the third stage negative sequence overcurrent element.				
I2>3 Time Delay	10s	0s	100s	0.01s
Setting for the operating time-delay for the third stage negative sequence overcurrent element.				
I2>4 Cells as for I2>3 Above				
I2> VTS Blocking	1111	Bit 00 = VTS blocks I2>1 Bit 01 = VTS blocks I2>2 Bit 02 = VTS blocks I2>3 Bit 03 = VTS blocks I2>4		
Logic settings that determine whether VT supervision blocks selected negative sequence overcurrent stages. Setting ‘0’ will permit continued non-directional operation.				
I2> Char. Angle	–60°	–95°	+95°	1°
Setting for the relay characteristic angle used for the directional decision.				
I2> V2pol Set	5	0.5	25	0.5
Setting determines the minimum negative sequence voltage threshold that must be present to determine directionality.				

Table 8 - Negative sequence overcurrent

3.8 Broken Conductor

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Broken Conductor	Disabled	Enabled/Disabled		N/A
Enables or disables the broken conductor function.				
I2/I1	0.2	0.2	1	0.01
Setting to determine the pick- up level of the negative to positive sequence current ratio.				
I2/I1 Time Delay	60s	0s	100s	1s
Setting for the function operating time delay.				

Table 9 - Broken conductor

3.9 Earth Fault

The back-up earth fault overcurrent protection included in the MiCOM P443/P446 provides four stage non-directional/directional three-phase overcurrent protection with independent time delay characteristics. All earth fault overcurrent and directional settings apply to all three phases but are independent for each of the four stages.

The first two stages of earth fault overcurrent protection have time-delayed characteristics which are selectable between Inverse Definite Minimum Time (IDMT), or Definite Time (DT). The third and fourth stages have definite time characteristics only.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
IN>1 Status	Enabled	Disabled, Enabled or Enabled VTS		
Setting that defines first stage overcurrent operating status. Depending of this setting, IN>1 will be enabled permanently or in case of Voltage Transformer Supervision (fuse fail) operation.				
IN>1 Function	IEC S Inverse	DT, IEC S Inverse, IEC V Inverse, IEC E inverse, UK LT Inverse IEEE M Inverse, IEEE V Inverse, IEEE E Inverse, US Inverse, US ST Inverse, IDG		
Setting for the tripping characteristic for the first stage earth fault overcurrent element.				
IN>1 Directional	Non-directional	Non-directional Directional Fwd Directional Rev		
This setting determines the direction of measurement for first stage element.				
IN>1 Current Set	0.2 x In	0.08 x In	4.0 x In	0.01 x In
Pick-up setting for first stage overcurrent element.				
IN1>1 IDG Is	1.5	1	4	0.1
This setting is set as a multiple of IN> setting for the IDG curve (Scandinavian) and determines the actual relay current threshold at which the element starts.				
IN>1 Time Delay	1	0	100	0.01
Setting for the time-delay for the definite time setting if selected for first stage element. The setting is available only when DT function is selected.				
IN>1 TMS	1	0.025	1.2	0.005
Setting for the time multiplier setting to adjust the operating time of the IEC IDMT characteristic.				
IN>1 Time Dial	1	0.01	100	0.01

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Setting for the time multiplier setting to adjust the operating time of the IEEE/US IDMT curves. The Time Dial (TD) is a multiplier on the standard curve equation, to achieve the required tripping time. The reference curve is based on TD = 1. Care: Certain manufacturers use a mid-range value of TD = 5 or 7, so it may be necessary to divide by 5 or 7 to achieve parity.				
IN>1 Reset Char.	DT	DT or Inverse		N/A
Setting to determine the type of reset/release characteristic of the IEEE/US curves.				
IN>1 tRESET	0s	0s	100s	0.01s
Setting that determines the reset/release time for definite time reset characteristic.				
IN1>1 IDG Time	1.2	1	2	0.01
Setting for the IDG curve used to set the minimum operating time at high levels of fault current.				
IN>2 Cells as for IN>1 above				
Setting the same as for the first stage earth fault overcurrent element.				
IN>3 Status	Enabled	Disabled, Enabled or Enabled VTS		
Setting that defines third stage overcurrent operating status. Depending of this setting, IN>3 will be enabled permanently or in case of Voltage Transformer Supervision (fuse fail) operation.				
IN>3 Directional	Non-directional	Non-directional Directional Fwd Directional Rev		N/A
This setting determines the direction of measurement for the earth fault overcurrent element.				
IN>3 Current Set	10 x In	0.08 x In	32 x In	0.01 x In
Pick-up setting for third stage earth fault overcurrent element.				
IN>3 Time Delay	0s	0s	100s	0.01s
Setting for the operating time-delay for third stage earth fault overcurrent element.				
IN>4 Cells as for IN>3 Above				
Settings the same as the third stage earth fault overcurrrent element.				
IN> Blocking	00001111	Bit 0 = VTS Blocks I>1, Bit 1 = VTS Blocks I>2, Bit 2 = VTS Blocks I>3, Bit 3 = VTS Blocks I>4, Bits 5 & 6 are not used.		
Logic Settings that determine whether blocking signals from VT supervision affect certain earth fault overcurrent stages. VTS Block - only affects directional earth fault overcurrent protection. With the relevant bit set to 1, operation of the Voltage Transformer Supervision (VTS), will block the stage. When set to 0, the stage will revert to Non-directional upon operation of the VTS. If IN> Status is set Enabled VTS, no blocking should be selected to provide earth fault clearance by earth fault overcurrent protection during VTS condition.				
IN> DIRECTIONAL				
IN> Char. Angle	-60°	–95°	+95°	1°
Setting for the relay characteristic angle used for the directional decision. The setting is visible only when Directional Fwd or Directional Rev is set.				
IN>Pol	Zero Sequence	Zero Sequence or Neg. Sequence		N/A
Setting that determines whether the directional function uses zero sequence or negative sequence voltage polarizing.				
IN>VNpol Set	1V	0.5V	80V	0.5V
Setting for the minimum zero sequence voltage polarizing quantity for directional decision. Setting is visible only when Zero Sequence polarization is set.				
IN>V2pol Set	1V	0.5V	25V	0.5V

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Setting for the minimum negative sequence voltage polarizing quantity for directional decision. Setting is visible only when Negative Sequence polarization is set.				
IN>I2pol Set	0.08 x In	0.08 x In	1 x In	0.01x In
Setting for the minimum negative sequence current polarizing quantity for directional decision. Setting is visible only when Negative Sequence polarization is set.				

Table 10 - Earth fault

3.10 Aided DEF

The column **GROUP x AIDED DEF** is used to set all parameters for operation of DEF (Directional Earth Fault aided scheme thresholds). As this configuration merely assigns pick up at the local end only, they need to be further configured to a selected Aided channel scheme under **GROUP x SCHEME LOGIC** to provide unit protection.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
DEF SCHEME				
DEF Status	Enabled	Enabled or Disabled		
To enable (activate) or disable (turn off) the Directional Earth Fault element that is used in an aided scheme (= ground overcurrent pilot scheme). This setting is invisible if disabled in CONFIGURATION column.				
DEF Polarizing	Zero Sequence	Neg. Sequence or Zero Sequence		
Setting that defines the method of DEF polarization. Either zero, or negative sequence voltage can be taken as the directional reference. When Zero Sequence is selected, this arms the Virtual Current Polarizing.				
DEF Char Angle	-60°	-95°	95°	1°
Setting for the relay characteristic angle used for the directional decision.				
DEF VNpol Set	1V	0.5V	40V	0.5V
Setting that must be exceeded by generated neutral displacement voltage VN (= 3.Vo) in order for the DEF function to be operational. As Virtual Current Polarizing will be in force when Zero sequence polarizing is used, this setting will normally have no relevance. If the relay phase selector (delta sensitivity typically 4% In) detects the faulted phase, this will artificially generate a large VNpol, typically equal to Vn (phase-ground). Only if the phase selector cannot phase select will this setting be relevant, as VNpol will then measure true VN. The setting is invisible if Neg. Sequence polarization is set.				
DEF V2pol Set	1V	0.5V	25V	0.5V
Setting that must be exceeded by generated negative sequence voltage V2 in order for the DEF function to be operational. The setting is invisible if Zero Sequence polarization is set.				
DEF Fwd Set	0.08 x In	0.05 x In	1 x In	0.01 x In
Setting the forward pickup current sensitivity for residual current (= 3.Io).				
DEF Rev Set	0.04 x In	0.03 x In	1 x In	0.01 x In
Setting the reverse pickup current sensitivity for residual current (= 3.Io).				

Table 11 - Aided DEF

3.11 Sensitive Earth Fault

If a system is earthed through a high impedance, or is subject to high ground fault resistance, the earth fault level will be severely limited. Consequently, the applied earth fault protection requires both an appropriate characteristic and a suitably sensitive setting range in order to be effective. A separate four-stage sensitive earth fault element is provided within the P443/P446 relay for this purpose, which has a dedicated input.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	**Max.**	
SEF/REF Options	SEF	SEF Enabled, Wattmetric SEF, HI Z REF		
Setting to select the type of sensitive earth fault protection function and the type of high-impedance function to be used.				
ISEF>1 Function	DT	Disabled, DT, IEC S Inverse, IEC V Inverse, IEC E inverse, UK LT Inverse IEEE M Inverse, IEEE V Inverse, IEEE E Inverse, US Inverse, US ST Inverse, IDG		
Setting for the tripping characteristic for the first stage sensitive earth fault element.				
ISEF>1 Direction	Non-directional	Non-directional Direction Fwd Direction Rev		N/A
This setting determines the direction of measurement for the first stage sensitive earth fault element.				
ISEF>1 Current	0.05 x In_{SEF}	0.005 x In_{SEF}	0.8 x In_{SEF}	0.00025 x In_{SEF}
Pick-up setting for the first stage sensitive earth fault element.				
ISEF>1 IDG Is	1.5	1	4	0.1
This setting is set as a multiple of ISEF> setting for the IDG curve (Scandinavian) and determines the actual relay current threshold at which the element starts.				
ISEF>1 Delay	1	0	200s	0.01s
Setting for the time delay for the first stage definite time element.				
ISEF>1 TMS	1	0.025	1.2	0.005
Setting for the time multiplier to adjust the operating time of the IEC IDMT characteristic.				
ISEF>1 Time Dial	1	0.1	100	0.1
Setting for the time multiplier to adjust the operating time of the IEEE/US IDMT curves.				
ISEF>1 Reset Char.	DT	DT or Inverse		N/A
Setting to determine the type of reset/release characteristic of the IEEE/US curves.				
ISEF>1 tRESET	0	0s	100s	0.01s
Setting to determine the reset/release time for definite time reset characteristic.				
ISEF>1 IDG Time	1.2	1	2	0.01
Setting for the IDG curve used to set the minimum operating time at high levels of fault current.				
ISEF>2 Cells as for ISEF>1 Above				
ISEF>3 Status	Disabled	Disabled or Enabled		N/A
Setting to enable or disable the third stage definite time sensitive earth fault element.				
ISEF>3 Direction	Non-directional	Non-directional Directional Fwd Directional Rev		N/A
This setting determines the direction of measurement for the third stage element.				
ISEF>3 Current	0.2 x In_{SEF}	0.005 x In_{SEF}	2.0 x In_{SEF}	0.001 x In_{SEF}
Pick-up setting for the third stage sensitive earth fault element.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
ISEF>3 Delay	1	0s	200s	0.01s
Setting for the operating time delay for third stage sensitive earth fault element.				
ISEF>4 Cells as for ISEF>3 Above				
ISEF> Func. Link	001111	Bit 0 = Bit 1 = Bit 2 = Bit 3 = Bit 4 = Bit 5 = Bit 6 = Bit 7 =	VTS Blks ISEF>1, VTS Blks ISEF>2, VTS Blks ISEF>3, VTS Blks ISEF>4, A/R Blks ISEF>3, A/R Blks ISEF>4, Not Used, Not Used.	
Settings that determine whether VT supervision and auto-reclose logic signals blocks selected sensitive earth fault stages.				
ISEF DIRECTIONAL				
ISEF> Char. Angle	90°	–95°	+95°	1°
Setting for the relay characteristic angle used for the directional decision.				
ISEF>VNpol Set	5	0.5V	88V	0.5V
Setting for the minimum zero sequence voltage polarizing quantity required for directional decision.				
IREF> Is	0.2 * In$_{sef}$	0.05 * In$_{sef}$	1 * In$_{sef}$	0.01 * In$_{sef}$
Pick-up setting for the High Impedance restricted earth fault element.				
WATTMETRIC SEF	Sub-heading in menu			
PN> Setting	9In$_{SEF}$ W	0	20In$_{SEF}$ W	0.05In$_{SEF}$ W
Setting for the threshold for the wattmetric component of zero sequence power. The power calculation is as follows: The PN> setting corresponds to: Vres x Ires x Cos (ϕ – ϕc) = 9 x Vo x Io x Cos (ϕ– ϕc) Where; ϕ = Angle between the Polarizing Voltage (-Vres) and the Residual Current ϕc = Relay Characteristic Angle (RCA) Setting (ISEF> Char Angle) Vres = Residual Voltage Ires = Residual Current Vo = Zero Sequence Voltage Io = Zero Sequence Current				

Table 12 - Sensitive earth fault

3.12 Residual Overvoltage (Neutral Voltage Displacement)

The NVD element within the MiCOM P443/P446 is of two-stage design, each stage having separate voltage and time delay settings. Stage 1 may be set to operate on either an IDMT or DT characteristic, whilst stage 2 may be set to DT only.

<table>
<tr><th>Menu Text</th><th>Default Setting</th><th colspan="2">Setting Range</th><th>Step Size</th></tr>
<tr><th></th><th></th><th>Min.</th><th>Max.</th><th></th></tr>
<tr><td>VN>1 Function</td><td>DT</td><td colspan="2">Disabled or DT or IDMT</td><td>N/A</td></tr>
<tr><td colspan="5">Setting for the tripping characteristic of the first stage residual overvoltage element.</td></tr>
<tr><td>VN>1 Voltage Set</td><td>5V</td><td>1V</td><td>80V</td><td>1V</td></tr>
<tr><td colspan="5">Pick-up setting for the first stage residual overvoltage characteristic.</td></tr>
<tr><td>VN>1 Time Delay</td><td>5s</td><td>0s</td><td>100s</td><td>0.01s</td></tr>
<tr><td colspan="5">Operating time delay setting for the first stage definite time residual overvoltage element.</td></tr>
<tr><td>VN>1 TMS</td><td>1</td><td>0.5</td><td>100</td><td>0.5</td></tr>
<tr><td colspan="5">Setting for the time multiplier setting to adjust the operating time of the IDMT characteristic.
The characteristic is defined as follows:
t = K / M - 1)
Where:
K = Time multiplier setting
t = Operating time in seconds
M = Derived residual voltage/relay setting voltage (VN> Voltage Set)</td></tr>
<tr><td>VN>1 tReset</td><td>0s</td><td>0s</td><td>100s</td><td>0.01s</td></tr>
<tr><td colspan="5">Setting to determine the reset/release definite time for the first stage characteristic</td></tr>
<tr><td>VN>2 Status</td><td>Disabled</td><td colspan="2">Disabled or Enabled</td><td>N/A</td></tr>
<tr><td colspan="5">Setting to enable or disable the second stage definite time residual overvoltage element.</td></tr>
<tr><td>VN>2 Voltage Set</td><td>10V</td><td>1V</td><td>80V</td><td>1V</td></tr>
<tr><td colspan="5">Pick-up setting for the second stage residual overvoltage element.</td></tr>
<tr><td>VN>2 Time Delay</td><td>10s</td><td>0s</td><td>100s</td><td>0.01s</td></tr>
<tr><td colspan="5">Operating time delay for the second stage residual overvoltage element.</td></tr>
</table>

Table 13 - Residual overvoltage (neutral voltage displacement)

3.13 Thermal Overload

The thermal overload function within the MiCOM P443/P446 is capable of being selected as a single time constant or dual time constant characteristic, dependent on the type of plant to be protected.

<table>
<tr><th>Menu Text</th><th>Default Setting</th><th colspan="2">Setting Range</th><th>Step Size</th></tr>
<tr><th></th><th></th><th>Min.</th><th>Max.</th><th></th></tr>
<tr><td>Characteristic</td><td>Single</td><td colspan="3">Disabled, Single or Dual</td></tr>
<tr><td colspan="5">Setting for the operating characteristic of the thermal overload element.</td></tr>
<tr><td>Thermal Trip</td><td>1 x In</td><td>0.08 x In</td><td>4 x In</td><td>0.01 x In</td></tr>
<tr><td colspan="5">Sets the maximum full load current allowed and the pick-up threshold of the thermal characteristic.</td></tr>
<tr><td>Thermal Alarm</td><td>70%</td><td>50%</td><td>100%</td><td>1%</td></tr>
<tr><td colspan="5">Setting for the thermal state threshold corresponding to a percentage of the trip threshold at which an alarm will be generated.</td></tr>
<tr><td>Time Constant 1</td><td>10 minutes</td><td>1 minute</td><td>200 minutes</td><td>1 minute</td></tr>
</table>

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Setting for the thermal time constant for a single time constant characteristic or the first time constant for the dual time constant characteristic.				
Time Constant 2	5 minutes	1 minute	200 minutes	1 minute
Setting for the second thermal time constant for the dual time constant characteristic.				

Table 14 - Thermal overload

3.14 Voltage Protection

Under and overvoltage protection included within the MiCOM P443/P446 consists of two independent stages. The measuring mode (ph-N or ph-ph) and operating mode (any phase or 3 phase) are configurable as a combination between Stage 1 and Stage 2, thus allowing completely independent operation for each stage.

Stage 1 may be selected as IDMT, DT or Disabled, within the **V<1 function** cell. Stage 2 is DT only and is enabled/disabled in the **V<2 status** cell.

Two stages are included to provide both alarm and trip stages, where required.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
UNDERVOLTAGE				
V< Measur't. Mode	V<1 & V<2 Ph-Ph	V<1 & V<2 Ph-Ph V<1 & V<2 Ph-N V<1Ph-Ph V<2Ph-N V<1Ph-N V<2Ph-Ph		N/A
Sets the combination of measured input voltage that will be used for the undervoltage elements. Note: If any stage is disabled, the associated text in the setting menu cell setting will remain visible but will not affect the operation of the stage that is enabled.				
V< Operate Mode	V<1 & V<2 Any Ph	V<1 & V<2 Any Ph V<1 & V<2 3Phase V<1AnyPh V<2 3Ph V<1 3Ph V<2AnyPh		N/A
Setting that determines whether any phase or all three phases has to satisfy the undervoltage criteria before a decision is made. *Note* *If any stage is disabled, the associated text in the setting menu cell setting will remain visible but will not affect the operation of the stage that is enabled.*				
V<1 Function	DT	Disabled DT IDMT		N/A
Tripping characteristic for the first stage undervoltage function. The IDMT characteristic available on the first stage is defined by the following formula: t = K / (1 - M) Where: K = Time multiplier setting t = Operating time in seconds M = Measured voltage/relay setting voltage (V< Voltage Set)				
V<1 Voltage Set	80V	10V	120V	1V
Sets the pick-up setting for first stage undervoltage element.				
V<1 Time Delay	10s	0s	100s	0.01s

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Setting for the operating time-delay for the first stage definite time undervoltage element.				
V<1 TMS	1	0.5	100	0.5
Setting for the time multiplier setting to adjust the operating time of the IDMT characteristic.				
V<1 Poledead Inh	Enabled	Enabled or Disabled		N/A
If the cell is enabled, the relevant stage will become inhibited by the pole dead logic. This logic produces an output when it detects either an open circuit breaker via auxiliary contacts feeding the relay opto inputs or it detects a combination of both undercurrent and undervoltage on any one phase. It allows the undervoltage protection to reset when the circuit breaker opens to cater for line or bus side VT applications.				
V<2 Status	Disabled	Enabled or Disabled		N/A
Setting to enable or disable the second stage undervoltage element.				
V<2 Voltage Set	60V	10V	120V	1V
This setting determines the pick-up setting for second stage undervoltage element.				
V<2 Time Delay	5s	0s	100s	0.01s
Setting for the operating time-delay for the second stage definite time undervoltage element.				
V<2 Poledead Inh	Enabled	Enabled Disabled		N/A
Similar function to V<1 Poledead Inhibit.				
OVERVOLTAGE				
V> Measur't. Mode	V<1 & V<2 Ph-Ph	V<1 & V<2 Ph-Ph V<1 & V<2 Ph-N V<1Ph-Ph V<2Ph-N V<1Ph-N V<2Ph-Ph		N/A
Sets the combination of measured input voltage that will be used for the overvoltage elements. Note: If any stage is disabled, the associated text in the setting menu cell setting will remain visible but will not affect the operation of the stage that is enabled.				
V> Operate Mode	V<1 & V<2 Any Ph	V<1 & V<2 Any Ph V<1 & V<2 3Phase V<1AnyPh V<2 3Ph V<1 3Ph V<2AnyPh		N/A
Setting that determines whether any phase or all three phases has to satisfy the overvoltage criteria before a decision is made. Note: If any stage is disabled, the associated text in the setting menu cell setting will remain visible but will not affect the operation of the stage that is enabled.				
V>1 Function	DT	Disabled, DT or IDMT		N/A
Tripping characteristic setting for the first stage overvoltage element. The IDMT characteristic available on the first stage is defined by the following formula: t = K/(M - 1) Where: K = Time multiplier setting t = Operating time in seconds M = Measured voltage/relay setting voltage (V<>Voltage Set)				
V>1 Voltage Set	130V	60V	185V	1V
Sets the pick-up setting for first stage overvoltage element.				
V>1 Time Delay	10s	0s	100s	0.01s
Setting for the operating time-delay for the first stage definite time overvoltage element.				
V>1 TMS	1	0.5	100	0.5
Setting for the time multiplier setting to adjust the operating time of the IDMT characteristic.				
V>2 Status	Disabled	Enabled or Disabled		N/A
Setting to enable or disable the second stage overvoltage element.				
V>2 Voltage Set	150V	60V	185V	1V

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
This setting determines the pick-up setting for the second stage overvoltage element.				
V>2 Time Delay	0.5s	0s	100s	0.01s
Setting for the operating time-delay for the second stage definite time overvoltage element.				
COMP OVERVOLTAGE				
V1>1 Cmp Funct	DT	Disabled, DT or IDMT		N/A
Tripping characteristic setting for the first stage compensated overvoltage element. The IDMT characteristic available on the first stage is defined by the following formula: t = K/(M - 1) Where: K = Time multiplier setting t = Operating time in seconds M = Remote calculated voltage/relay setting voltage (V<>Voltage Set)				
V1>1 Cmp Vlt Set	75V	60V	110V	1V
Sets the pick-up setting for first stage overvoltage element. This is set in terms of the phase to neutral voltage.				
V1>1 Cmp Tim Dly	10s	0s	100s	0.01s
Setting for the operating time-delay for the first stage definite time compensated overvoltage element.				
V1>1 CmpTMS	1	0.5	100	0.5
Setting for the time multiplier setting to adjust the operating time of the IDMT characteristic.				
V1>2 Cmp Status	Disabled	Enabled or Disabled		N/A
Setting to enable or disable the second stage compensated overvoltage element.				
V1>2 Vlt Set	85V	60V	110V	1V
This setting determines the pick-up setting for the second stage overvoltage element.				
V1>2 CmpTim Dly	0.5s	0s	100s	0.01s
Setting for the operating time-delay for the second stage definite time compensated overvoltage element.				

Table 15 - Voltage protection

3.15 Frequency Protection

The relay includes 4 stages of underfrequency and 2 stages of overfrequency protection to facilitate load shedding and subsequent restoration. The underfrequency stages may be optionally blocked by a pole dead (CB Open) condition.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
FREQ. PROTECTION GROUP 1				
UNDERFREQUENCY				
F<1 Status	Enabled	Enabled or Disabled		N/A
Setting to enable or disable the first stage underfrequency element.				
F<1 Setting	49.5 Hz	45Hz	65Hz	0.01Hz
Setting that determines the pick-up threshold for the first stage underfrequency element.				
F<1 Time Delay	4s	0s	100s	0.01s
Setting that determines the minimum operating time-delay for the first stage underfrequency element.				
F<2 Status (same as stage 1)	Disabled	Enabled or Disabled		N/A
F<3 Status (same as stage 1)	Disabled	Enabled or Disabled		N/A
F<4 Status (same as stage1)	Disabled	Enabled or Disabled		N/A
F< Function Link	0000			Bit 0 F<1 U/V Block Bit 1 F<2 U/V Block Bit 2 F<3 U/V Block Bit 3 F<4 U/V Block
Settings that determines whether undervoltage level (setting CB FAIL & P.DEAD/ POLEDEAD VOLTAGE/V<) signal block the underfrequency elements.				
OVERFREQUENCY				
F>1 Status	Enabled	Enabled or Disabled		N/A
Setting to enable or disable the first stage overfrequency element.				
F>1 Setting	50.5 Hz	45Hz	65Hz	0.01Hz
Setting that determines the pick-up threshold for the first stage overfrequency element.				
F>1 Time Delay	2s	0s	100s	0.01s
Setting that determines the minimum operating time-delay for the first stage overfrequency element.				
F>2 Status (same as stage1 above)	Disabled	Enabled or Disabled		N/A

Table 16 - Frequency protection

3.16 Independent Rate of Change of Frequency Protection

The relay provides four independent stages of rate of change of frequency protection (df/dt+t). Depending upon whether the rate of change of frequency setting is set positive or negative, the element will react to rising or falling frequency conditions respectively, with an incorrect setting being indicated if the threshold is set to zero.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
DF/DT PROTECTION GROUP 1				
df/dt Avg. Cycles	6	6	12	6
This setting is available for calculating the rate of change of frequency measurement over a fixed period of either 6 or 12 cycles.				
df/dt>1 Status	Enabled	Enabled or Disabled		N/A
Setting to enable or disable the first stage df/dt element.				
df/dt>1 Setting	2.000 Hz/s	100.0mHz/s	10Hz/s	100mHz/s
Pick-up setting for the first stage df/dt element.				
df/dt>1 Dir'n.	Negative	Negative/Positive/Both		N/A
This setting determines whether the element will react to rising or falling frequency conditions respectively, with an incorrect setting being indicated if the threshold is set to zero.				
df/dt>1 Time	500.0ms	0	100	10ms
Minimum operating time-delay setting for the first stage df/dt element.				
df/dt>2 Status (same as stage1)	Enabled	Enabled or Disabled		N/A
df/dt>3 Status (same as stage 1)	Enabled	Enabled or Disabled		N/A
df/dt>4 Status (same as stage1)	Enabled	Enabled or Disabled		N/A

Table 17 - DF/DT protection group 1

3.17 Circuit Breaker Fail and Pole Dead Detection Function

The CB Fail function consists of a two-stage circuit breaker fail function that can be initiated by:

- Current based protection elements
- Voltage based protection elements
- External protection elements

For current-based protection, the reset condition is based on undercurrent operation to determine that the CB has opened. For the non-current based protection, the reset criteria may be selected using a setting for determining a CB Failure condition.

It is common practice to use low set undercurrent elements in protection relays to indicate that circuit breaker poles have interrupted the fault or load current, as required.

The Pole Dead detection consists of a two user settable level detectors:

- Undercurrent
- Undervoltage

The undercurrent setting is shared with CB Fail protection. Both, undercurrent and undervoltage settings are also used for CNV (Current No Volt) function in TOC protection.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
CB FAIL & P. DEAD				
BREAKER FAIL				
CB Fail 1 Status	Enabled	Enabled or Disabled		
Setting to enable or disable the first stage of the circuit breaker function.				
CB Fail 1 Timer	0.2s	0s	10s	0.01s
Setting for the circuit breaker fail timer stage 1, during which breaker opening must be detected. There are timers per phase to cope with evolving faults, but the timer setting is common.				
CB Fail 2 Status	Disabled	Enabled or Disabled		
Setting to enable or disable the second stage of the circuit breaker function.				
CB Fail 2 Timer	0.4s	0s	10s	0.01s
Setting for the circuit breaker fail timer stage 2, during which breaker opening must be detected.				
Volt Prot. Reset	Prot. Reset & I<	I< Only, CB Open & I<, Prot. Reset & I<		
Setting which determines the elements that will reset the circuit breaker fail time for voltage protection function initiated circuit breaker fail conditions.				
Ext. Prot. Reset	Prot. Reset & I<	I< Only, CB Open & I<, Prot. Reset & I<		
Setting which determines the elements that will reset the circuit breaker fail time for external protection function initiated circuit breaker fail conditions.				
WI Prot. Reset	Disabled	Disabled or Enabled		
When Enabled, CB Fail timers will be reset by drop off of a weak infeed trip condition, providing that WI trip logic is activated.				
UNDERCURRENT				
I< Current Set	0.05 x In	0.02 x In	3.2 x In	0.01 x In
Setting that determines the circuit breaker fail timer reset current for overcurrent based protection circuit breaker fail initiation. This setting is also used in the pole dead logic to determine the status of the pole (dead or live)				
ISEF< Current	0.02x In_{SEF}	0.001x In_{SEF}	0.8x In_{SEF}	0.00005 x In
Setting that determines the circuit breaker fail timer reset current for Sensitive earth fault (SEF) protection circuit breaker fail initiation.				
POLEDEAD VOLTAGE				
V<	38.10V	10V	40V	0.1V

Table 18 - Circuit breaker fail and pole dead detection

3.18 Supervision (VTS, CTS, Inrush Detection and Special Weak Infeed Blocking)

The VTS feature within the relay operates on detection of Negative Phase Sequence (NPS) voltage without the presence of negative phase sequence current.

The CT supervision feature operates on detection of derived zero sequence current, in the absence of corresponding derived zero sequence voltage that would normally accompany it.

The Special Weak Infeed Blocking is not normally applied, and is described in detail later in this service manual.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
SUPERVISION				
VTS Mode	Measured + MCB	Measured + MCB, Measured Only or MCB Only		
Setting that determines the method to be used to declare VT failure				
VTS Status	Blocking	Disabled, Blocking, Indication		
This setting determines whether the following operations will occur upon detection of VTS. VTS set to provide alarm indication only. Optional blocking of voltage dependent protection elements. Optional conversion of directional overcurrent elements to non-directional protection (available when set to blocking mode only). These settings are found in the function links cell of the relevant protection element columns in the menu.				
VTS Reset Mode	Manual	Manual, Auto		
The VTS block will be latched after a user settable time delay VTS Time Delay. Once the signal has latched then two methods of resetting are available. The first is manually via the front panel interface (or remote communications) and secondly, when in Auto mode, provided the VTS condition has been removed and the 3 phase voltages have been restored above the phase level detector settings for more than 240ms.				
VTS Time Delay	5s	1s	10s	0.1s
Setting that determines the operating time-delay of the element upon detection of a voltage supervision condition.				
VTS I> Inhibit	10 x In	0.08 x In	32 x In	0.01 x In
The setting is used to override a voltage supervision block in the event of a phase fault occurring on the system that could trigger the voltage supervision logic.				
VTS I2> Inhibit	0.05 x In	0.05 x In	0.5 x In	0.01 x In
The setting is used to override a voltage supervision block in the event of a fault occurring on the system with negative sequence current above this setting which could trigger the voltage supervision logic.				
INRUSH DETECTION				
I> 2nd Harmonic	20%	10%	100%	5%
If the level of second harmonic in any phase current or neutral current exceeds the setting, inrush conditions will be recognized by changing the status of four DDB signals from low to high in the Programmable Scheme Logic (PSL). The user then has a choice to use them further in the PSL in accordance with the application.				
WEAK INFEED BLK				
WI Inhibit	Disabled	Disabled or Enabled		
This setting enables (turns on) or disables (turns off) a special feature to cover scenarios when there is a very weak positive or negative sequence source behind the relay, but the zero sequence infeed is large. Special to stub-end transformer feeding, where the stub end has no generation, but has solid earthing at a Yd transformer neutral.				
I0/I2 Setting	3	2	3	0.1
If the ratio of zero sequence current to negative sequence current exceeds the setting, all protection elements such as Distance, DEF and Delta that could potentially operate during a genuine weak infeed condition will be inhibited. This setting will be visible only if WI Inhibit is enabled.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
CT SUPERVISION (CTS)				
CTS Mode	Disabled	Enabled or Disabled		N/A
Setting to enable or disable the current transformer supervision element.				
CTS Status	Restrain	Restrain, Indication		
This setting determines whether the following operations will occur upon detection of CTS. CTS set to provide alarm indication only. CTS set to restrain local protection *Note The settings are visible if CTS Mode is not disabled.*				
CTS Reset Mode	Manual	Manual or Auto		
The CTS block will be latched after a user settable time delay CTS Time Delay. Once the signal has latched then two methods of resetting are available. The first is manually via the front panel interface (or remote communications) and secondly, when in Auto mode, provided the CTS condition has been removed. The setting is visible if CTS Mode is not disabled.				
CTS Time Delay	5s	0s	10s	1s
Setting that determines the operating time-delay of the element upon detection of a current transformer supervision condition.				
CTS VN < Inhibit	5V	500mV	22V	500mV
Setting that determines the level of zero sequence (residual) voltage that must be avoided to ensure a valid current transformer supervision decision.				
CTS IN> Set	0.1 x In	0.08 x In	4 x In	0.01 x In
This setting determines the level of zero sequence current that must be present for a valid current transformer supervision condition.				

Table 19 - Supervision

3.19 System Checks (Check Sync Function)

The System Checks functionality differs between the P443 and the P446 since the P443 can only control one circuit breaker, whereas the P446 can control two. Accordingly, therefore, the settings are different for the two relays.

3.19.1.1 P443 System Checks (Check Sync. Function)

The MiCOM P443 has a two-stage Check Synchronization function that can be set independently.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
VOLTAGE MONITORING				
Live Voltage	32V	1V	132V	0.5V
Sets the minimum voltage threshold above which a line or bus is to be recognized as being ‘Live’.				
Dead Voltage	13V	1V	132V	0.5V
Sets the voltage threshold below which a line or bus to be recognized as being Dead.				
CHECK SYNC.				
Stage 1	Enabled	Enabled or Disabled		
Setting to enable or disable the first stage check sync. element.				
CS1 Phase Angle	20°	0°	90°	1°

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Sets the maximum phase angle difference between the line and bus voltage for the first stage check sync. element phase angle criteria to be satisfied.				
CS1 Slip Control	Frequency	Frequency/Both/Timer/None		
Setting that determines whether slip control is by slip frequency only, frequency + timer or timer only criteria to satisfy the first stage check sync. conditions. If slip control by timer or frequency + timer is selected, the combination of phase angle and timer settings determines an effective maximum slip frequency, calculated as: $\frac{2 \times A}{T \times 360}$ Hz. for Check Sync. 1, or Where: A = Phase angle setting (°) T = Slip timer setting (seconds)				
CS1 Slip Freq.	50mHz	10mHz	1Hz	10mHz
Sets the maximum frequency difference between the line and bus voltage for the first stage check sync. element slip frequency to be satisfied.				
CS1 Slip Timer	1s	0s	99s	0.01s
Minimum operating time-delay setting for the first stage check sync. element.				
CS2 Status	Enabled	Enabled or Disabled		
Setting to enable or disable the second stage check sync. element.				
CS2 Phase Angle	20°	0°	90°	1°
Sets the maximum phase angle difference between the line and bus voltage for the second stage check sync. element phase angle criteria to be satisfied.				
CS2 Slip Control	Frequency	Frequency/Both/Timer/None		
Setting that determines whether slip control is by slip frequency only, frequency + timer or timer only criteria to satisfy the CS1 conditions. If Slip Control by Timer or Frequency + Timer is selected, the combination of Phase Angle and Timer settings determines an effective maximum slip frequency, calculated as: $\frac{A}{T \times 360}$ Hz. for Check Sync. 2, or Where: A = Phase angle setting (°) T = Slip timer setting (seconds) Unlike Check Sync. 1, Check Sync. 2 only permits closure for decreasing angles of slip, therefore the circuit breaker should always close within the limits defined by Check Sync. 2.				
CS2 Slip Freq.	50mHz	10mHz	1Hz	10mHz
Slip frequency setting for the second stage check sync. element.				
CS2 Slip Timer	1s	0s	99s	0.01s
Setting for the second stage Check Sync. slip timer.				
CS Undervoltage	54V	10V	132V	0.5V
Sets an undervoltage threshold above which the line and bus voltage must be to satisfy the Check Sync. condition if selected in the CS Voltage Block cell.				
CS Overvoltage	130V	60V	185V	0.5V
Sets an overvoltage threshold above below which the line and bus voltage must be to satisfy the Check Sync. condition if selected in the CS Voltage Block cell.				
CS Diff. Voltage	6.5V	1V	132V	0.5V

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Sets the voltage magnitude threshold between the line and bus volts below that the line and bus voltage difference must be to satisfy the Check Sync. condition if selected in the CS Voltage Block cell.				
CS Voltage Block	V<	V</V>/Vdiff.>/V< and V>/V< and Vdiff>/ V> and Vdiff>/V< V> and Vdiff>/None		
Selects whether an undervoltage, overvoltage and voltage difference thresholds for the line and bus voltages must be satisfied in order for the Check Sync. conditions to be satisfied.				
SYSTEM SPLIT				
SS Status	Enabled	Enabled or Disabled		
Setting to enable or disable the system split function - to detect a line and bus which are not possible to synchronize.				
SS Phase Angle	120°	90°	175°	1°
Sets the maximum phase angle difference between the line and bus voltage, which must be exceeded, for the System Split condition to be satisfied.				
SS Under V Block	Enabled	Enabled or Disabled		
Activates and undervoltage block criteria				
SS Undervoltage	54V	10V	132V	0.5V
Sets an undervoltage threshold above which the line and bus voltage must be to satisfy the System Split condition.				
SS Timer	1s	0s	99s	0.01s
The System Split output remains set for as long as the System Split criteria are true, or for a minimum period equal to the System Split Timer setting, whichever is longer.				

Table 20 - P443 system checks

3.19.1.2 P446 System Checks (Check Sync. Function)

The MiCOM P446 has a two stage Check Synchronization function that can be set independently for each circuit breaker.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
VOLTAGE MONITORS				
Live Line	32V	5V	132V	0.5V
Line is considered Live with voltage above this setting.				
Dead Line	13V	5V	132V	0.5V
Line is considered Dead with voltage below this setting.				
Live Bus 1	32V	5V	132V	0.5V
Bus 1 is considered Live with voltage above this setting.				
Dead Bus 1	13V	5V	132V	0.5V
Bus 1 is considered Dead with voltage below this setting.				
Live Bus 2	32V	5V	132V	0.5V
Bus 2 is considered Live with voltage above this setting.				
Dead Bus 2	13V	5V	132V	0.5V
Bus 2 is considered Dead with voltage below this setting.				
CS UV	54V	5V	120V	0.5V
Check Synch Undervoltage setting decides that System Check Synchronism logic for CB1 will be blocked if V< is one of the selected options in setting CB1 CS Volt.Blk (48 8E), and either line or bus voltage is below this setting. System Check Synchronism for CB2 will be blocked if V< is one of the selected options in setting CB2 CS Volt. Blk (48 9C), and either line or bus voltage is below this setting.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
CS OV	130V	60V	200V	0.5V
Check Synch Overvoltage setting decides that System Check Synchronism logic for CB1 is blocked if V> is one of the selected options in setting CB1 CS Volt. Blk (48 8E), and either line or bus voltage is above this setting. System Check Synchronism for CB2 is blocked if V> is one of the selected options in setting CB2 CS Volt. Blk (48 9C), and either line or bus voltage is above this setting.				
Sys Checks CB1	Disabled	Enabled or Disabled		
Setting to enable or disable both stages of system checks for reclosing CB1. If System Checks CB1 is set to Disabled, all other menu settings associated with synchronism checks for CB1 become invisible, and a DDB (880) signal SChksInactiveCB1 is set.				
CB1 CS Volt. Blk	V<	V<, V>, Vdiff.>, V< and V>, V< and Vdiff>, V> and Vdiff>, V< V> and Vdiff>, None		
Setting to determine which, if any, conditions should block synchronism check for CB1 (undervoltage V<, overvoltage V>, and/or voltage differential Vdiff etc.) for the line and bus voltages.				
CB1 CS1 Status	Enabled	Enabled or Disabled		
Setting to enable or disable the stage 1 synchronism check elements for auto-reclosing and manual closing CB1.				
CB1 CS1 Angle	20°	0°	90°	1°
Maximum permitted phase angle between Line and Bus 1 voltages for first stage synchronism check element to re-close CB1.				
CB1 CS1 VDiff	6.5V	1V	120V	0.5V
Check Synch Voltage differential setting decides that stage 1 System Check Synchronism logic for CB1 is blocked if Vdiff> is one of the selected options in setting CB1 CS Volt.Blk (48 8E), and voltage magnitude difference between line and bus 1 voltage is above this setting.				
CB1 CS1 SlipCtrl	Enabled	Enabled or Disabled		
Setting to enable or disable blocking of synchronism check stage 1 for re-closing CB1 by excessive frequency difference (slip) between line and bus voltages (refer to setting CB1 CS1 SlipFreq).				
CB1 CS1 SlipFreq	50mHz	5mHz	2Hz	5mHz
If CB1 CS1 Slip Ctrl is enabled, synchronism check stage 1 is blocked for reclosing CB1 if measured frequency difference between line and bus voltages is greater than this setting.				
CB1 CS2 Status	Disabled	Enabled or Disabled		
Setting to enable or disable the stage 2 synchronism check elements for auto-reclosing and manual closing CB1.				
CB1 CS2 Angle	20°	0°	90°	1°
Maximum permitted phase angle between Line and Bus 1 voltages for second stage synchronism check element to re-close CB1.				
CB1 CS2 VDiff	6.5V	1V	120V	0.5V
Check Synch Voltage differential setting decides that stage 2 System Check Synchronism logic for CB1 is blocked if Vdiff> is one of the selected options in setting CB1 CS Volt.Blk (48 8E), and voltage magnitude difference between line and bus 1 voltage is above this setting.				
CB1 CS2 SlipCtrl	Enabled	Enabled or Disabled		
Setting to enable or disable blocking of synchronism check stage 2 for reclosing CB1 by excessive frequency difference (slip) between line and bus voltages (refer to setting CB1 CS2 SlipFreq).				
CB1 CS2 SlipFreq	50mHz	5mHz	2Hz	5mHz
If CB1 CS2 Slip Ctrl is enabled, synchronism check stage 2 is blocked for reclosing CB1 if measured frequency difference between line and bus voltages is greater than this setting.				
CB1 CS2 Adaptive	Disabled	Enabled or Disabled		
Setting to enable or disable Adaptive CB closing with System Check Synchronism stage 2 closing for CB1: logic uses set CB1 Cl Time to issue CB1 close command at such a time that the predicted phase angle difference when CB1 main contacts touch is as close as possible to 0 degrees. If Adaptive closing is disabled, the logic issues CB1 close command as soon as phase angle comes within set limit at CB1 CS2 Angle.				
CB1 Cl Time	50.0ms	10.0ms	0.5s	1.0ms

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
This sets CB1 closing time, from receipt of CB1 close command until main contacts touch.				
Sys Checks CB2	Disabled	Enabled or Disabled		
Setting to enable or disable both stages of system checks for re-closing CB2. If System Checks CB2 is set to Disabled, all other menu settings associated with synchronism checks for CB2 become invisible, and a DDB (1484) signal SChksInactiveCB2 is set.				
CB2 CS Volt. Blk	V<	V<, V>, Vdiff.>, V< and V>, V< and Vdiff>, V> and Vdiff>, V< V> and Vdiff>, None		
Setting to determine which, if any, conditions should block synchronism check for CB2 (undervoltage V<, overvoltage V>, and/or voltage differential Vdiff etc.) for the line and bus voltages.				
CB2 CS1 Status	Enabled	Enabled or Disabled		
Setting to enable or disable the stage 1 synchronism check elements for auto-reclosing and manual closing CB2.				
CB2 CS1 Angle	20°	0°	90°	1°
Maximum permitted phase angle between Line and Bus 2 voltages for first stage synchronism check element to re-close CB2.				
CB2 CS1 Vdiff	6.5V	1V	120V	0.5V
Check Synch Voltage differential setting decides that stage 1 System Check Synchronism logic for CB2 is blocked if Vdiff> is one of the selected options in setting CB2 CS Volt.Blk (48 9C), and voltage magnitude difference between line and bus 2 voltage is above this setting.				
CB2 CS1 SlipCtrl	Enabled	Enabled or Disabled		
Setting to enable or disable blocking of synchronism check stage 1 for re-closing CB2 by excessive frequency difference (slip) between line and bus voltages (refer to setting CB2 CS1 SlipFreq).				
CB2 CS1 SlipFreq	50mHz	5mHz	2Hz	5mHz
If CB2 CS1 Slip Ctrl is enabled, synchronism check stage 1 is blocked for re-closing CB2 if measured frequency difference between line and bus voltages is greater than this setting.				
CB2 CS2 Status	Disabled	Enabled or Disabled		
Setting to enable or disable the stage 2 synchronism check elements for auto-reclosing and manual closing CB2.				
CB2 CS2 Angle	20°	0°	90°	1°
Maximum permitted phase angle between Line and Bus 2 voltages for second stage synchronism check element to re-close CB2.				
CB2 CS2 Vdiff	6.5V	1V	120V	0.5V
Check Synch Voltage differential setting decides that stage 2 System Check Synchronism logic for CB2 is blocked if Vdiff> is one of the selected options in setting CB2 CS Volt.Blk (48 9C), and voltage magnitude difference between line and bus 2 voltage is above this setting.				
CB2 CS2 SlipCtrl	Enabled	Enabled or Disabled		
Setting to enable or disable blocking of synchronism check stage 2 for re-closing CB2 by excessive frequency difference (slip) between line and bus voltages (refer to setting CB2 CS2 SlipFreq).				
CB2 CS2 SlipFreq	50mHz	5mHz	2Hz	5mHz
If CB2 CS2 Slip Ctrl is enabled, synchronism check stage 2 is blocked for re-closing CB2 if measured frequency difference between line and bus voltages is greater than this setting.				
CB2 CS2 Adaptive	Disabled	Enabled or Disabled		
Setting to enable or disable Adaptive CB closing with System Check Synchronism stage 2 closing for CB2: logic uses set CB1 Cl Time to issue CB2 close command at such a time that the predicted phase angle difference when CB2 main contacts touch is as close as possible to 0 degrees. If adaptive closing is disabled, the logic issues CB2 close command as soon as phase angle comes within set limit at CB2CS2 Angle.				
CB2 Cl Time	50.0ms	10.0ms	0.5s	1.0ms
This sets CB2 closing time, from receipt of CB2 close command until main contacts touch.				
MAN SYS CHECKS				
Num CBs	CB1 only	CB1 only, CB2 only, CB1 & CB2.		

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
This setting is only visible if the CB Control by cell (Cell 0701 under CB CONTROL column) is Enabled. If visible, the setting dictates which of the circuit breakers (CB1 only, CB2 only, or both CB1 & CB2) can be manually closed.				
CB1M SC required	Disabled	Enabled or Disabled		
This setting determines whether a system check (e.g. live bus/dead line etc.) is required for any manual (operator-controlled) closure of CB1. If Enabled, system check is required for closure. If Disabled, system check is not required.				
CB1M SC CS1	Disabled	Enabled or Disabled		
This setting enables CB1 to close by manual control when the system satisfies all the System Check Synchronism Stage 1 conditions as listed under the setting CB1 CS1 Status in the SYSTEM CHECKS column.				
CB1M SC CS2	Disabled	Enabled or Disabled		
This setting enables CB1 to close by manual control when the system satisfies all the System Check Synchronism Stage 2 conditions as listed under the setting CB1 CS2 Status in the SYSTEM CHECKS column.				
CB1M SC DLLB	Disabled	Enabled or Disabled		
This setting enables CB1 to close by manual control when the dead line & live bus1 conditions are satisfied as set in the SYSTEM CHECKS column.				
CB1M SC LLDB	Disabled	Enabled or Disabled		
This setting enables CB1 to close by manual control when the live line & dead bus1 conditions are satisfied as set in the SYSTEM CHECKS column.				
CB1M SC DLDB	Disabled	Enabled or Disabled		
This setting enables CB1 to close by manual control when the dead line & dead bus1 conditions are satisfied as set in the SYSTEM CHECKS column.				
CB2M SC required	Disabled	Enabled or Disabled		
This setting determines whether a system check (e.g. live bus / dead line etc.) is required for any manual (operator-controlled) closure of CB2. If Enabled, system check is required for closure. If Disabled, system check is not required.				
CB2M SC CS1	Disabled	Enabled or Disabled		
This setting enables CB2 to close by manual control when system satisfies all the System Check Synchronism Stage 1 conditions as listed under the setting CB2 CS1 Status in the SYSTEM CHECKS column.				
CB2M SC CS2	Disabled	Enabled or Disabled		
This setting enables CB2 to close by manual control when the system satisfies all the System Check Synchronism Stage 2 conditions as listed under setting CB2 CS2 status in the SYSTEM CHECKS column.				
CB2M SC DLLB	Disabled	Enabled or Disabled		
This setting enables CB2 to close by manual control when the dead line & live bus2 conditions are satisfied as set in the SYSTEM CHECKS column.				
CB2M SC LLDB	Disabled	Enabled or Disabled		
This setting enables CB2 to close by manual control when the live line & dead bus2 conditions are satisfied as set in the SYSTEM CHECKS column.				
CB2M SC DLDB	Disabled	Enabled or Disabled		
This setting enables CB2 to close by manual control when the dead line & dead bus2 conditions are satisfied as set in the SYSTEM CHECKS column.				

Table 21 - P446 system checks

3.20 Auto-Reclose Function

The auto-reclose functionality differs between the P443 and the P446 since the P443 can only control one circuit breaker, whereas the P446 can control two. Accordingly, therefore, the settings are different for the two relays.

3.20.1.1 P443 Auto-Reclose Function

The MiCOM P443 will initiate auto-reclose for fault clearances by any instantaneous trip allocated in the PSL to DDB Trip Inputs A, B or C (DDB 530, 531 or 532 respectively). The default PSL includes Zone 1 trip and distance aided trips. In addition, other distance zones, Aided DEF, Directional comparison, phase and earth overcurrent protection and Trip On Re-close (TOR) may be set to initiate auto-reclose, when required. This is done in the settings (shown here after). Protection such as voltage, frequency, thermal etc. will block auto-reclose.

The following shows the relay settings for the auto-reclose function, which must be set in conjunction with the Circuit Breaker Control settings under main Menu. The available setting ranges and factory defaults are shown:

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Single Pole Shot	1	1	4	1
Sets the number of auto-reclose shots/cycles applicable for single phase faults. *Note This setting also applies when auto-reclose is configured in 3 pole tripping applications. Even though the trip mode may be 3 pole only, the fact that the initiation was a single phase fault type is memorized.* In single pole tripping applications, for a setting of "N" shots, the full cycle will allow one single pole trip and re-closure, plus (N-1) subsequent three phase shots. When the number of recurrent single pole faults exceeds the setting, the AR will lockout.				
Three Pole Shot	1	1	4	1
Sets the number of auto-reclose shots/cycles applicable for a multiphase fault. Where the phase selector has identified more than one faulted phase, or has been unable to phase select only a single phase, the applicable sequence is "3 Pole". When the number of 3ph trips exceeds the setting, the AR will lock out.				
1 Pole Dead Time	0.5s	0.05s	5s	0.01s
Sets the dead time (CB open interval) for a single pole auto-reclose cycle, first shot.				
Dead Time 1	0.3s	0.05s	30s	0.01s
Sets the dead time for the first auto-reclose cycle, except where a single pole trip has occurred.				
Dead Time 2	60s	1s	1800s	1s
Sets the dead time for the second auto-reclose cycle.				
Dead Time 3	60s	1s	3600s	1s
Sets the dead time for the third auto-reclose cycle.				
Dead Time 4	60s	1s	3600s	1s
Sets the dead time for the fourth auto-reclose cycle.				
CB Healthy Time	5s	1s	3600s	1s
If on completion of the dead time, the CB Healthy input is low, and remains low for a period given by the CB Healthy Time timer, lockout will result and the circuit breaker will remain open.				
Reclaim Time	180s	1s	600s	1s
Sets the auto-reclose reclaim timer - the time after which the sequence counter will reset to zero.				
AR Inhibit Time	5s	0.01s	600s	0.01s
With this setting, auto-reclose initiation is inhibited for a period equal to setting A/R Inhibit Time following a manual circuit breaker closure.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Check Sync Time	5s	0.01s	9999s	0.01s
Time window during which set System Check conditions must be satisfied for a successful re-close. If not, AR will lockout after time has elapsed.				
Z2T AR	Block AR	No action, Block AR or Initiate AR		
Setting that determines impact of time delayed zone 2 on AR operation. Set Initiate AR if the trip should initiate a cycle, and Block AR if a time delayed trip should cause lockout. Set No action if Zone 2 tripping should exert no specific logic control on the re-closer.				
Z3T AR	Block AR	No action, Block AR or Initiate AR		
Similar application to Z3T AR. Selection for Zone 3 trips.				
ZPT AR	Block AR	No action, Block AR or Initiate AR		
Similar application to ZPT AR. Selection for Zone 3 trips.				
Z4T AR	Block AR	No action, Block AR or Initiate AR		
Similar application to Z4T AR. Selection for Zone 4 trips.				
DEF Aided AR	Block AR	Block AR or Initiate AR		
Setting that determines impact of aided Directional Earth Fault protection (DEF) on AR operation.				
Dir Aided AR	Block AR	Block AR or Initiate AR		
Setting that determines impact of aided Directional Comparison protection (DEF) on AR operation.				
TOR AR	Block AR	Block AR or Initiate AR		
Setting that determines impact of Trip On Re-close (TOR) on AR operation.				
I>1 AR	No Action	No action, Block AR or Initiate AR		
Setting that determines impact of the first stage overcurrent protection on AR operation.				
I>2 to I>4 Cells as for I>1 Above				
IN>1 AR	No Action	No action, Block AR or Initiate AR		
Setting that determines impact of the first stage earth fault overcurrent protection on AR operation.				
IN>2 to IN>4 Cells as for IN>1 Above				
Mult Phase AR	BAR 3 Phase	BAR 3 Phase/BAR 2 and 3 Phase/ Allow AR		
Setting that determines impact of any multiphase fault on AR operation. If, for example, BAR 2 and 3 Phase is selected, the AR will be blocked for any multiphase fault. If BAR 3 Phase is selected, the AR will be blocked only for faults affecting all three phases together (A-B-C). The Allow AR selection is used where all faulted phase combinations may be permitted to initiate an auto-reclose sequence.				
Dead Time Start	Protection Operation	Protection Operation or Protection Reset		N/A
Setting that determines whether the dead time is started when the protection operates or when the protection trip command resets.				
Discrim. Timer	0.1s	0.1s	5s	0.01s
Pick up time delay after which any evolving fault during the dead time will be considered as a second (new) fault. If an evolving fault occurs while the timer is still running, the force 3 ph trip internal signal will be issued and the 1 Pole Dead Time that is running following the initial single pole trip will stop and start 'Dead Time 1' instead.				
ISEF>1 AR	No Action	No action, Block AR or Initiate AR		
Setting that determines impact of the first stage sensitive earth fault overcurrent protection on AR operation.				
ISEF>2 to ISEF>4 Cells as for ISEF>1 Above				
SYSTEM CHECKS				
CS1 Close Enable	Disabled	Enabled or Disabled		N/A

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Enables auto-reclose with check synchronization. Only allows auto-reclose when the system satisfies the Check Sync. Stage 1 settings.				
CS2 Close Enable	Disabled	Enabled or Disabled		N/A
Enables auto-reclose with check synchronization. Only allows auto-reclose when the system satisfies the Check Sync. Stage 2 settings				
LiveLine/Dead Bus	Disabled	Enabled or Disabled		N/A
Enables auto-reclose with Live (hot) line and Dead busbar.				
DeadLine/LiveBus	Disabled	Enabled or Disabled		N/A
Enables auto-reclose with Dead line and Live (hot) busbar.				
DeadLine/Dead Bus	Disabled	Enabled or Disabled		N/A
Enables auto-reclose with Dead line and Dead busbar.				
C/S AR Immediate	Disabled	Enabled or Disabled		N/A
When enabled this setting allows the set dead time to be bypassed, by implementing a repeat re-closer function. Provided that both line ends have cleared the fault, the line will have gone dead. If the line is then energized from the remote end first, the line will become live again. On detection of a live line, in synchronism with the local bus, immediate reclosing can be permitted.				
Sys. Chk. on Shot 1	Enabled	Enabled or Disabled		N/A
Can be used to disable system checks on the first auto-reclose shot.				

Table 22 - P443 auto-reclose

3.20.1.2 P446 Auto-Reclose Function

The MiCOM P446 can be set to initiate auto-reclose for fault clearances by Zone 1 trips, distance aided trips, other distance zones, Aided DEF, Directional comparison, phase and earth overcurrent protection and Trip On Re-close (TOR). This is configured in the settings (shown here after). Other protection functions such as voltage, frequency, thermal etc. will block auto-reclose.

The following shows the relay settings for the auto-reclose function, which must be set in conjunction with the Circuit Breaker Control settings under main Menu. The available setting ranges and factory defaults are shown:

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Num CBs	CB1 Only	CB1 only, CB2 only, Both CB1 & CB2		
Setting defines which CB(s) are active for the specific installation: CB1 only, CB2 only or both CB1 & CB2.				
Lead/Foll AR Mode	L3P F3P	L1P F1P, L1P F3P, L3P F3P, L1/3P F1/3P, L1/3P F3P, Opto.		

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Setting determines which auto-reclose modes are permitted for leader/follower circuit breakers. The auto-reclose scheme provides single phase or three phase auto-reclosing of a feeder switched by two circuit breakers. The two circuit breakers are normally arranged to re-close sequentially with one, designated the Leader circuit breaker, re-closing after a set dead time followed, if the leader CB remains closed, by the second circuit breaker, designated the Follower circuit breaker after a further delay (follower time). L1P F1P: both leader and follower are configured for single phase auto-reclosing. L1P F3P: the leader is configured for single phase auto-reclosing, whilst the follower is configured for three phase auto-reclosing. L3P F3P: both leader and follower are configured for three phase auto-reclosing. L1/3P F1/3P: both leader and follower are configured for either single phase or three phase auto-reclosing. L1/3P F3P: the leader is configured for single phase or three phase auto-reclosing, whilst the follower is configured for three phase auto-reclosing only. Opto: the auto-reclosing mode of the leader and follower are controlled by opto input signals (Opto) mapped via DDBs (1497) Lead AR 1P, (1498) Lead AR 3P, (1409) Follower AR 1P, and (1410) Follower AR 3P.				
AR Mode	AR 3P	AR 1P, AR 1/3P, AR 3P, AR Opto		
If the Num CBs setting (cell 4950 {above} in the AUTORECLOSE column) is set to CB1 Only, or CB2 Only, then this setting determines which auto-reclose modes are permitted for the circuit breaker: single phase (AR 1P) only, both single phase and three phase (AR 1/3P), three phase only (AR 3P), or the auto-reclosing mode is controlled by opto input signals (Opto) mapped via DDBs (1497) Lead AR 1P and (1498) Lead AR 3P.				
Leader Select By	Leader by Menu	Leader by Menu, Leader by Opto, Leader by Control		
Setting which determines how the preferred leader CB is selected - can be by menu setting, HMI command or by designated opto input. If Leader Select By: is set to Leader by Opto, then the preferred leader CB is: CB1 if input DDB(1408) CB2 Lead is low, or CB2 if input DDB (1408) CB2 Lead is high If Leader Select By: is set to Leader by Control, then user control setting CTRL CB2 Lead under CB CONTROL in the IED menu determines the preferred leader by applying set/reset commands (If Set then CB2 is leader, If Reset then CB1 is leader).				
Select Leader	Sel Leader CB1	Sel Leader CB1, Sel Leader CB2		
If Leader Select By is set to Leader by Menu in the previous cell, then setting Select Leader becomes visible, and determines which CB is the preferred leader.				
BF if LFail Cls	Enabled	Enabled or Disabled		
BF if L Fail Cls = Block Follower re-close if Leader CB Fails to close. This setting determines whether a follower CB should lock out without re-closing, or continue to re-close, if the leader CB fails to re-close when the leader CB close command is given. If BF if L Fail Cls is set to Enable, follower CB re-closing is locked out if the leader fails to close. If BF if L Fail Cls is set to Disable, the follower CB can continue its re-close cycle if the leader CB fails to close. (See also setting Dynamic F/L).				
Dynamic F/L	Disabled	Enabled or Disabled		
Dynamic F/L = Dynamic change from follower to leader status during an auto-reclose cycle if the leader CB fails to close. If setting BF if Lfail Cls is set to Disabled, then setting Dynamic F/L becomes visible and determines whether the follower CB should assume leader status and re-close immediately if the leader CB should fail to close, or whether it should continue as follower and re-close after the Follower Time delay. Dynamic F/L set to Enabled selects immediate follower re-close if the leader CB fails to close; Dynamic F/L set to Disabled selects the follower to re-close after the Follower Time if leader CB fails to close.				
AR Shots	1	1	4	1

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
This setting determines how many re-close attempts (shots) are permitted for any single fault incident before it is treated as persistent and auto-reclosing is locked out. For example if AR Shots = 2, a second re-close attempt is initiated if the protection re-trips during the reclaim time following one re-close attempt, but locks out if the protection re-trips during the reclaim time after a second re-close attempt.				
Multi Phase AR	Allow Autoclose	Allow Autoclose, BAR 2 and 3 ph, BAR 3 phase		
This setting determines whether auto-reclosing is permitted or blocked for two phase or three phase faults.				
Discrim Time	100.0 ms	5 ms	5 second	5 ms
Discrim Time = Discriminating Time. This is a setting which determines whether a fault on another phase (evolving or developing fault) after single phase trip and auto-reclose has been initiated by a single phase fault stops the single phase cycle and starts a three phase auto-reclose cycle provided this second fault (evolving fault) occurs BEFORE the Discrimination Time elapsed. It forces a lockout if second fault (evolving fault) occurs AFTER Discrimination Time has elapsed but before Single Phase Dead Time elapses.				
CB IS Time	100.0 ms	5 s	200 second	100 ms
CB IS Time = CB In Service Time. This is a timer setting for which a CB must remain closed (and optionally the line be live) before it is considered to be In Service.				
CB IS MemoryTime	500.0 ms	10 ms	1 second	10 ms
CB IS Memory Time is a timer setting which allows a CB In Service state to be remembered for a short period following changeover of the CB auxiliary switch contacts to a CB Open state. This may occasionally be necessary for a few types of CB with exceptionally fast acting auxiliary switch contacts which allow the auto-reclose scheme logic to detect the CB opening before it detects an associated protection operation.				
DT Start by Prot	Protection Reset	Protection Reset , Protection Op, Disable		
DT Start by Prot = Dead Time Start By Protection action. If DT Start by Prot is set to Disable, a dead time start is not directly affected by protection operation or reset, but is enabled by other conditions or events (see settings: 3PDTStart WhenLD and DTStart by CB Op). If DT Start by Prot is set to Protection Op, the dead time starting is enabled when the auto-reclose initiation signal is received from the protection. If DT Start by Prot is set to Protection Reset, the dead time starting is inhibited until the auto-reclose initiation signal from the protection resets.				
3PDTStart WhenLD	Disabled	Enabled or Disabled		
3PDTStart When LD = three phase auto-reclose dead time starts when the line has gone dead. If Enabled, the line is required to go dead before a 3 phase auto-reclose dead time can start. If Disabled, dead time can start when other selected conditions are satisfied, irrespective of line volts.				
DTStart by CB Op	Disabled	Enabled or Disabled		
If Enabled, a dead time start is permitted only when the CB has tripped. If Disabled, a dead time start is permitted when other selected conditions are satisfied, irrespective of the CB position.				
Dead Line Time	5.0 sec	1.0 sec	9999 s	1.0 sec
When 3PDTStart When LD is Enabled, and the line does not go dead within the set Dead Line Time period, then the logic will force the auto-reclose sequence to lockout after expiry of this time.				
SP AR Dead Time	500.0 ms	0.0 sec	10 s	10 ms
Dead time setting for single phase auto-reclose.				
3P AR DT Shot 1	300.0 ms	10.0 ms	300 s	10 ms
Dead time setting for three phase auto-reclose (first shot).				
3P AR DT Shot 2	60.0 s	1.0 s	9999 s	1 s
Dead time setting for three phase auto-reclose (2nd shot).				
3P AR DT Shot 3	60.0 s	1.0 s	9999 s	1 s
Dead time setting for three phase auto-reclose (3rd shot).				
3P AR DT Shot 4	60.0 s	1.0 s	9999 s	1 s
Dead time setting for three phase auto-reclose (4th shot).				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Follower Time	5.0 s	100.0 ms	300 s	10 ms
Time delay setting for follower CB re-closing after leader CB has re-closed.				
SPAR ReclaimTime	60.0 s	1.0 s	600 s	1 s
Reclaim time setting following single phase auto-reclosure.				
3PAR ReclaimTime	180.0 s	1.0 s	600 s	1 s
Reclaim time setting following three phase auto-reclosure.				
AR CBHealthy Time	5s	0.01s	9999s	0.01s
Maximum waiting time to enable CB Closing by auto-reclose. Input DDBs (436/437) are used for CB1 Healthy & CB2 Healthy respectively to enable CB1 and CB2 Close by auto-reclose. If the set time runs out with the input DDB: “CBx Healthy” low (= 0), alarm AR CBx Unhealthy (DDB307 or 329 for CB1 & CB2 respectively) is set and the CBx auto-reclose sequence is cancelled.				
AR CheckSync Time	5s	0.01s	9999s	0.01s
Maximum waiting time for relevant signals CB1L SCOK or CB1F SCOK from system check logic, to enable CB1 Close by auto-reclose. Same waiting time setting applies to input signals CB2L SCOK or CB2F SCOK to enable CB2 Close by auto-reclose. If the set time runs out with the input signal CBx SCOK low (= 0), System Check Synchronization fail alarm AR CBx NO C/S (DDB 308 or 330 for CB1 & CB2 respectively) is set and the CBx auto-reclose sequence is cancelled.				
Z1 AR	Initiate AR	Block AR or Initiate AR		
Setting that determines impact of instantaneous zone 1 on AR operation.				
Dist Aided AR	Initiate AR	Block AR or Initiate AR		
Setting that determines impact of the aided distance schemes tripping on AR operation.				
Z2T AR	Block AR	No action, Block AR or Initiate AR		
Setting that determines impact of time delayed zone 2 on AR operation. Set Initiate AR if the trip should initiate a cycle, and Block AR if a time delayed trip should cause lockout. Set No action if Zone 2 tripping should exert no specific logic control on the re-closer.				
Z3T AR	Block AR	No action, Block AR or Initiate AR		
Similar application to Z3T AR. Selection for Zone 3 trips.				
ZPT AR	Block AR	No action, Block AR or Initiate AR		
Similar application to ZPT AR. Selection for Zone 3 trips.				
Z4T AR	Block AR	No action, Block AR or Initiate AR		
Similar application to Z4T AR. Selection for Zone 4 trips.				
DEF Aided AR	Block AR	Block AR or Initiate AR		
Setting that determines impact of aided Directional Earth Fault protection (DEF) on AR operation.				
Dir Aided AR	Block AR	Block AR or Initiate AR		
Setting that determines impact of aided Directional Comparison protection (DEF) on AR operation.				
TOR AR	Block AR	Block AR or Initiate AR		
Setting that determines impact of Trip On Re-close (TOR) on AR operation.				
I>1 AR	No Action	No action, Block AR or Initiate AR		
Setting that determines impact of the first stage overcurrent protection on AR operation.				
I>2 AR to I>4 AR Cells as for I>1 AR Above				
IN>1 AR	No Action	No action, Block AR or Initiate AR		
Setting that determines impact of the first stage earth fault overcurrent protection on AR operation.				
IN>2 AR to IN>4 AR Cells as for IN>1 AR Above				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
ISEF>1 AR	No Action	No action, Block AR or Initiate AR		
Setting that determines impact of the first stage sensitive earth fault overcurrent protection on AR operation.				
ISEF>2 AR to ISEF>4 AR Cells as for ISEF>1AR Above				
AR SYS CHECKS				
CB1L SC all	Disabled	Enabled or Disabled		
This setting determines whether a system check (e.g. live bus / dead line etc.) is required for any auto-reclose of CB1 as leader. If Enabled, system check is required for some or all re-closures. If Disabled, system check is not required for any re-closures.				
CB1L SC Shot 1	Disabled	Enabled or Disabled		
This setting determines whether a system check (e.g. live bus / dead line etc.) is required for the first shot re-closure of CB1 as leader. If Enabled, system check is required for the first shot re-closure. If Disabled, system check is not required for the first shot re-closure.				
CB1L SC ClsNoDly	Disabled	Enabled or Disabled		
If CB1L SC ClsNoDly is Enabled, CB1 can re-close as leader as soon as the synchro check conditions are satisfied, without waiting for the dead time to elapse. This option is sometimes required for the second line end to re-close onto a line with delayed auto-reclosing (typical cycle: first line end re-closes after the dead time with live bus & dead line, then the second line end re-closes immediately with live bus & live line in synchronism).				
CB1L SC CS1	Disabled	Enabled or Disabled		
This setting enables CB1 to auto-reclose as leader when the system satisfies all the System Check Synchronism Stage 1 criteria as defined under CB1 CS1 Status settings in the SYSTEM CHECKS column.				
CB1L SC CS2	Disabled	Enabled or Disabled		
This setting enables CB1 to auto-reclose as leader when the system satisfies all the System Check Synchronism Stage 2 criteria as defined under the setting CB1 CS2 status in the SYSTEM CHECKS column.				
CB1L SC DLLB	Disabled	Enabled or Disabled		
This setting enables CB1 to auto-reclose as leader when the dead line & live bus1 conditions are satisfied as set in the SYSTEM CHECKS column.				
CB1L SC LLDB	Disabled	Enabled or Disabled		
This setting enables CB1 to auto-reclose as leader when the live line & dead bus1 conditions are satisfied as set in the SYSTEM CHECKS column.				
CB1L SC DLDB	Disabled	Enabled or Disabled		
This setting enables CB1 to auto-reclose as leader when the dead line & dead bus1 conditions are satisfied as set in the SYSTEM CHECKS column.				
CB2L SC all	Disabled	Enabled or Disabled		
This setting determines whether a system check (e.g. live bus / dead line or sync check) is required for any auto-reclose of CB2 as leader. If Enabled, system check is required for some or all re-closures. If Disabled, system check is not required for any re-closures.				
CB2L SC Shot 1	Disabled	Enabled or Disabled		
This setting determines whether a system check (e.g. live bus / dead line etc.) is required for the first shot re-closure of CB2 as leader. If Enabled, system check is required for the first shot re-closure. If Disabled, system check is not required for the first shot re-closure.				
CB2L SC ClsNoDly	Disabled	Enabled or Disabled		
If CB2L SC ClsNoDly is Enabled, CB2 can re-close as leader as soon as the synchro check conditions are satisfied, without waiting for the dead time to elapse. This option is sometimes required for the second line end to re-close on a line with delayed auto-reclosing (typical cycle: the first line end re-closes after the dead time with live bus & dead line, then the second line end re-closes immediately with live bus & live line in synchronism).				
CB2L SC CS1	Disabled	Enabled or Disabled		

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
This setting enables CB2 to auto-reclose as leader when the system satisfies all the System Check Synchronism Stage 1 criteria as defined under CB2 CS1 Status settings in the SYSTEM CHECKS column.				
CB2L SC CS2	Disabled	Enabled or Disabled		
This setting enables CB2 to auto-reclose as leader when the system satisfies all the System Check Synchronism Stage 2 criteria as defined under “CB2 CS2 Status” settings in the SYSTEM CHECKS column.				
CB2L SC DLLB	Disabled	Enabled or Disabled		
This setting enables CB2 to auto-reclose as leader when the dead line & live bus 2 conditions are satisfied as set in the SYSTEM CHECKS column.				
CB2L SC LLDB	Disabled	Enabled or Disabled		
This setting enables CB2 to auto-reclose as leader when the live line & dead bus 2 conditions are satisfied as set in the SYSTEM CHECKS column.				
CB2L SC DLDB	Disabled	Enabled or Disabled		
This setting enables CB2 to auto-reclose as leader when the dead line & dead bus 2 conditions are satisfied as set in the SYSTEM CHECKS column.				
CB1F SC all	Disabled	Enabled or Disabled		
This setting determines whether a system check (e.g. live bus / dead line etc.) is required for any auto-reclose of CB1 as follower. If Enabled, system check is required for some or all re-closures. If Disabled, system check is not required for any reclosures.				
CB1F SC Shot 1	Disabled	Enabled or Disabled		
This setting determines whether a system check (e.g. live bus / dead link etc.) is required for the first shot re-closure of CB1 as follower. If Enabled, system check is required for the first shot re-closure. If Disabled, system check is not required for the first shot re-closure.				
CB1F SC CS1	Disabled	Enabled or Disabled		
This setting enables CB1 to auto-reclose as follower when the system satisfies all the System Check Synchronism Stage 1 conditions as listed under setting CB1 CS1 Status in the SYSTEM CHECKS column.				
CB1F SC CS2	Disabled	Enabled or Disabled		
This setting enables CB1 to auto-reclose as follower when system satisfies all the System Check Synchronism Stage 2 conditions as listed under setting CB1 CS2 Status in the SYSTEM CHECKS settings.				
CB1F SC DLLB	Disabled	Enabled or Disabled		
This setting enables CB1 to auto-reclose as follower when the dead line & live bus1 conditions are satisfied in the SYSTEM CHECKS column.				
CB1F SC LLDB	Disabled	Enabled or Disabled		
This setting enables CB1 to auto-reclose as follower when the live line & dead bus1 conditions are satisfied in the SYSTEM CHECKS column.				
CB1F SC DLDB	Disabled	Enabled or Disabled		
This setting enables CB1 to auto-reclose as follower when the dead line & dead bus1 conditions are satisfied in the SYSTEM CHECKS settings.				
CB2F SC all	Disabled	Enabled or Disabled		
This setting determines whether a system check (e.g. live bus / dead line etc.) is required for any auto-reclose of CB2 as follower. If Enabled, system check is required for some or all re-closures. If Disabled, system check is not required for any reclosures.				
CB2F SC Shot 1	Disabled	Enabled or Disabled		
This setting determines whether a system check (e.g. live bus / dead line etc.) is required for the first shot re-closure of CB2 as follower. If Enabled, system check is required for the first shot re-closure. If Disabled, system check is not required for the first shot re-closure.				
CB2F SC CS1	Disabled	Enabled or Disabled		
This setting enables CB2 to auto-reclose as follower when the system satisfies all the System Check Synchronism Stage 1 conditions as listed under setting CB2 CS1 Status in the SYSTEM CHECKS column.				
CB2F SC CS2	Disabled	Enabled or Disabled		

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
This setting enables CB2 to auto-reclose as follower when system satisfies all the System Check Synchronism Stage 2 conditions as listed under setting CB2 CS2 Status in the SYSTEM CHECKS settings.				
CB2F SC DLLB	Disabled	Enabled or Disabled		
This setting enables CB2 to auto-reclose as follower when the dead line & live bus 2 conditions are satisfied in the SYSTEM CHECKS column.				
CB2F SC LLDB	Disabled	Enabled or Disabled		
This setting enables CB2 to auto-reclose as follower when the live line & dead bus 2 conditions are satisfied in the SYSTEM CHECKS column.				
CB2F SC DLDB	Disabled	Enabled or Disabled		
This setting enables CB2 to auto-reclose as follower when the dead line & dead bus 2 conditions are satisfied in the SYSTEM CHECKS settings.				

Table 23 - P446 auto-reclose

3.21 Input Labels

The column **GROUP x INPUT LABELS** is used to individually label each opto input that is available in the relay. The text is restricted to 16 characters and is available if **Input Labels** are set visible under CONFIGURATION column.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	**Max.**	
Opto Input 1	Input L1	16 characters custom name		
Label for Opto Input 1				
Opto Input x	Input Lx	16 characters custom name		
Label for other Opto Inputs. x = up to 32, depending on relay model.				

Table 24 - Input labels

3.22 Output Labels

The column **GROUP x OUTPUT LABELS** is used to individually label each output relay that is available in the relay. The text is restricted to 16 characters and is available if **Output Labels** are set visible under CONFIGURATION column.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	**Max.**	
Relay 1	Output R1	16 characters custom name		
Label for output relay 1				
Relay x	Output Rx	16 characters custom name		
Label for other output relays. x = up to 32, depending on relay model.				

Table 25 - Output labels

4 INTEGRAL TELEPROTECTION SETTINGS

4.1 EIA(RS)232 InterMiCOM

InterMiCOM operates via an EIA(RS)232 physical output on the back of the 2nd rear communication board. It provides 8 independently settable digital signals that can be conveyed between line ends. The InterMiCOM teleprotection is restricted to 2 ends. InterMiCOM input and output mapping has to be done in the Programmable Scheme Logic (PSL).

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
INTERMiCOM COMMS				
IM Input Status	00000000			
Displays the status of each InterMiCOM input signal, with IM1 signal starting from the right. When loop back mode is set, all bits will display zero.				
IM Output Status	00000000			
Displays the status of each InterMiCOM output signal.				
Source Address	1	1	10	1
Setting for the unique relay address that is encoded in the InterMiCOM sent message.				
Receive Address	2	1	10	1
The aim of setting addresses is to establish pairs of relays which will only communicate with each other. Should an inadvertent channel misrouting or spurious loopback occur, an error will be logged, and the erroneous received data will be rejected. As an example, in a 2 ended scheme the following address setting would be correct: Local relay: Source Address = 1, Receive Address = 2 Remote relay: Source Address = 2, Receive Address = 1				
Baud Rate	9600	600, 1200, 2400, 4800, 9600, or 19200		
Setting of the signaling speed in terms of number of bits per second. The speed will match the capability of the MODEM or other characteristics of the channel provided.				
Ch Statistics	Visible	Invisible or Visible		
Settings that makes visible or invisible Channel Statistics on the LCD. The statistic is reset by either relay powering down or using the Reset Statistics cell.				
Rx Direct Count	0			
Displays the number of valid Direct Tripping messages since last counter reset.				
Rx Perm Count	0			
Displays the number of valid Permissive Tripping messages since last counter reset.				
Rx Block Count	0			
Displays the number of valid Blocking messages since last counter reset.				
Rx NewData Count	0			
Displays the number of different messages (change events) since last counter reset.				
Rx Errored Count	0			
Displays the number of invalid received messages since last counter reset.				
Lost Messages	0			
Displays the difference between the number of messages that were supposed to be received (based on set Baud Rate) and actual valid received messages since last reset.				
Elapsed Time	0			
Displays the time in seconds since last counter reset.				
Reset Statistics	No	Yes or No		

Menu Text	**Default Setting**	**Setting Range**		**Step Size**
		Min.	**Max.**	
Command that allows all Statistics and Channel Diagnostics to be reset.				
Ch Diagnostics	Visible	Invisible or Visible		
Setting that makes visible or invisible Channel Diagnostics on the LCD. The diagnostic is reset by either relay powering down or using the Reset Statistics cell.				
DATA CD Status	OK, FAIL, or Absent			
Indicates when the DCD line (pin 1 on EIA232 Connector) is energized. OK = DCD is energized FAIL = DCD is de-energized Absent = 2nd Rear port board is not fitted				
FrameSync Status	OK, FAIL, Absent or Unavailable			
Indicates when the message structure and synchronization is valid. OK = Valid message structure and synchronization FAIL = Synchronization has been lost Absent = 2nd Rear port board is not fitted Unavailable = Hardware error present				
Message Status	OK, FAIL, Absent or Unavailable			
Indicates when the percentage of received valid messages has fallen below the IM Msg Alarm Lvl setting within the alarm time period. OK = Acceptable ratio of lost messages FAIL = Unacceptable ratio of lost messages Absent = 2nd Rear port board is not fitted Unavailable = Hardware error present				
Channel Status	OK, FAIL, Absent or Unavailable			
Indicates the state of the InterMiCOM communication channel. OK = Channel healthy FAIL = Channel failure Absent = 2nd Rear port board is not fitted Unavailable = Hardware error present				
IM H/W Status	OK, Read Error, Write Error, or Absent			
Indicates the state of InterMiCOM hardware OK = InterMiCOM hardware healthy Read or Write Error = InterMiCOM failure Absent = 2nd Rear port is not fitted or failed to initialize.				
Loopback Mode	Disabled	Disabled, Internal or External		
Setting to allow testing of the InterMiCOM channel. When Internal is selected, only the local InterMiCOM software functionality is tested, whereby the relay will receive its own sent data. 'External' setting allows a hardware and software check, with an external link required to jumper the sent data onto the receive channel. During normal service condition Loopback mode must be disabled.				
Test Pattern	11111111	00000000	11111111	-
Allows specific bit statuses to be inserted directly into the InterMiCOM message, to substitute real data. This is used for testing purposes.				
Loopback Status	OK, FAIL or Unavailable			

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Indicates the status of the InterMiCOM loopback mode OK = Loopback software (and hardware) is working correctly FAIL = Loopback mode failure Unavailable = Hardware error present.				

Table 26 - INTERMiCOM COMMS

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
INTERMiCOM CONF				
IM Msg Alarm Lvl	25%	0%	100%	0.1%
Setting that is used to alarm for poor channel quality. If during the fixed 1.6s window the ratio of invalid messages to the total number of messages that should be received (based upon the Baud Rate setting) exceeds the above threshold, a Message Fail alarm will be issued.				
IM1 Cmd Type	Blocking	Disabled, Direct or Blocking		
Setting that defines the operative mode of the InterMiCOM_1 signal. Selecting the channel response for this bit to Blocking allows fastest signaling, whereas setting to Direct offers higher security at the expense of speed.				
IM1 FallBackMode	Default	Default or Latching		
Setting that defines the status of IM1 signal in case of heavy noise and message synchronization being lost. If set to Latching the last valid IM1 status will be maintained until the new valid message is received. If set to ‘Default’, the IM1 status, pre-defined by the user in IM1 DefaultValue cell will be set. A new valid message will replace IM1 DefaultValue, once the channel recovers.				
IM1 DefaultValue	1	0	1	1
Setting that defines the IM1 fallback status.				
IM1 FrameSyncTim	0.02s	0.01s	1.5s	0.01s
Time delay after which IM1 DefaultValue is applied, providing that no valid message is received in the meantime.				
IM2 to IM4	Cells as for IM1 above			
IM5 Cmd Type	Direct	Disabled, Direct or Permissive		
Setting that defines the operative mode of the InterMiCOM_5 signal. Selecting the channel response for this bit to Permissive offers higher dependability, whereas setting to Direct offers higher security.				
IM5 FallBackMode	Default	Default or Latching		
As for IM1				
IM5 DefaultValue	0	0	1	1
Setting that defines the IM5 fallback status.				
IM5 FrameSyncTim	0.01s	0.01s	1.5s	0.01s
Time delay after which IM5 DefaultValue is applied.				
IM6 to IM8	Cells as for IM5 above			

Table 27 - INTERMiCOM conf

4.2 56/64 kbit/s Fiber Teleprotection - InterMiCOM64

InterMiCOM^{64} is a fiber-optic based teleprotection scheme, described in detail in the Operation and Application chapters of this manual. Only relays ordered with fiber ports support this feature. The communication uses 56 or 64 kbit/s channels.

In the settings listed here, Channel1 and Channel2 refer to the communications channels, and are associated with configuring the communications ports fitted to the co-processor board.

Each setting below that refers to Channel 2 is associated with the communications setting of the second communications channel (where fitted) and is visible only when 3 Terminal or Dual redundant teleprotection configuration is set.

Note *InterMiCOM^{64} provides 2 groups of 8 InterMiCOM^{64} commands. These are referenced as Channel 1 and Channel 2. They have a subtly different meaning and should not be confused with communications channels 1 and 2.*

InterMiCOM^{64} input and output mapping has to be done in the Programmable Scheme Logic (PSL).

Menu Text	Default Setting	Setting Range		Step Size
		Min.	**Max.**	
PROT COMMS/IM64				
Scheme Setup	2 Terminal	2 Terminal, Dual Redundant or 3 Terminal		
Settings to determine how many relay ends are connected in the teleprotection scheme for the protected line, with two or three ends possible. For a plain two terminal line, there is an additional option to use dual communication channels, to implement redundancy (i.e. employ a parallel “hot-standby” path).				
Address	0-0	0-0, 1-A…20-A, 1-B….20-B		
Setting for the unique relay address that is encoded in the InterMiCOM^{64} sent message. The aim of setting the address is to establish pairs of relays which will only communicate with each other. Should an inadvertent fiber/MUX misrouting or spurious loopback occur, an error will be logged, and the erroneous received data will be rejected. As an example, in a 2 ended scheme the following address setting would be correct: Local relay: 1-A Remote relay: 1-B Address 0-0 is a universal address, whereby any relay will be free to communicate with any other (equivalent to disabling of the unique addressing). When PROT COMMS/IM64 is set to loop back mode, the address 0-0 will replace any existing address in the relay.				
Address	0-0	0-0, 1-A…20-A, 1-B….20-B, 1-C…20-C		
In 3 terminal schemes, communicating groups of three relays may be configured.				
Comm Mode	Standard	Standard or IEEE C37.94		
Setting that defines the data format that will be transmitted on the fiber outputs from the relay. If the Multiplexer accepts direct fiber inputs according to IEEE C37.94, the IEEE C37.94 setting is selected. For a direct fiber link between relays, and where the MUX connection is in electrical format (G.703 or V.35 or X.21), the Standard message format needs to be set. For a setting change to take effect, rebooting of the relay will be required. The Comm Mode setting applies to both channels.				
Baud Rate Ch 1	64kbits/s	56kbits/s or 64kbits/s		
Channel 1 data rate setting for signaling between ends. The setting will depend on the MUX electrical interface, set 64kbit/s for G.703 and X.21, or generally 56kbit/s for V.35. For direct fiber connection between relays, 64kbit/s will offer slightly faster data transmission. The setting is invisible when IEEE C37.94 Comm Mode is selected.				
Baud Rate Ch 2	64kbits/s	56kbits/s or 64kbits/s		

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
As Baud Rate Ch1 cell.				
Clock Source Ch1	Internal	Internal or External		
Setting that defines which clock source is used to synchronize data transmissions over channel 1. The setting will depend on communications configuration and external clock source availability. If relays are connected direct fiber over channel 1, Internal setting should be selected. If channel 1 is routed via a multiplexer, either setting may be required (see Application Notes).				
Clock Source Ch2	Internal	Internal or External		
Setting that matches the clock source being used for data synchronization over channel 2.				
Ch1 N*64kbits/s	1	Auto, 1, 2, 3, …..or 12		
Setting for channel 1 when connected to an IEEE C37.94 compliant multiplexer. When set to Auto the P443/P446 will configure itself to match the multiplexer. The setting is visible only when IEEE C37.94 Comm Mode is selected.				
Ch2 N*64kbits/s	1	Auto, 1, 2, 3, …..or 12		
Setting for channel 2 when connected to an IEEE C37.94 compliant multiplexer. When set to Auto the P443/P446 will configure itself to match the multiplexer. The setting is visible only when IEEE C37.94 Comm Mode is selected.				
Comm Fail Timer	10s	0.1s	600s	0.1s
Time delay after which the Channel Fail Alarm will be issued providing that no messages were received during the Channel Timeout period or the Alarm Level is exceeded.				
Comm Fail Mode	Ch 1 and 2 Fail	Ch 1 Failure/Ch 2 Failure/Ch 1 or Ch 2 Fail/Ch 1 and Ch 2 Fail		
Fail mode setting that triggers the Channel Fail Alarm, providing that the Dual Redundancy or 3 ended scheme is set. Normally the alarm would be raised for any loss of an operational channel (logical “OR” combination). However, when relays in a 3 ended scheme are deliberately operated in Chain topology “AND” logic may be used, for indication when the scheme becomes finally inoperative, with no self-healing (signal re-routing) mode possible.				
Channel Timeout	0.1s	0.1s	10s	0.1s
A rolling time window beyond which any of the 8 IM signals that are set to Default will be replaced by the corresponding IM_X Default Value setting, providing that no valid message is received on that channel in the meantime. The Chnl Fail Alarm timer will be also initiated. If only one channel is used, each out of 16 IM signals available that is set to Default will convert to corresponding IM_X Default Value. If a Dual redundant or 3 ended scheme is selected, each out of 8 IM signals available that is set to ‘Default’ will convert to corresponding IM_X Default Value, but only for the affected channel.				
Alarm Level	25%	0%	100%	1%
Setting that is used to alarm for poor channel quality. If during a fixed 100ms rolling window the number of invalid messages divided by the total number of messages that should be received (based upon the Baud Rate setting) increase above the threshold, a Channel Fail Alarm timer will be initiated.				
Prop Delay Stats	Enable	Enable or Disable		
A setting whereby the InterMiCOM messages can be errored if the propagation delay time exceeds a set value.				
Max Ch1 Prop Delay	15ms	1ms	50ms	1ms
Visible only when Prop Delay Stats in enabled, this is the time setting for channel 1.				
Max Ch1 Prop Delay	15ms	1ms	50ms	1ms
Max Ch2 Prop Delay	15ms	1ms	50ms	1ms
Visible only when Prop Delay Stats in enabled, this is the time setting for channel 2.				
IM1 Cmd Type	Permissive	Direct or Permissive		

Menu Text	Default Setting	Setting Range		Step Size
		Min.	**Max.**	
Setting that defines the operative mode of the received InterMiCOM_1 signal. When Direct tripping is chosen, for security reasons 2 consecutive valid messages have to be received before a change in the signal status will be acknowledged. That will impose an additional 1-2ms delay compared to Permissive mode. Set Direct in Direct Transfer Tripping (Intertripping) applications. Set Permissive to accommodate any Permissive or Blocking scheme.				
IM1 FallBackMode	Default	Default or Latching		
Setting that defines the status of IM1 signal in case of heavy noise and message synchronization being lost. If set to Latching the last valid IM1 status will be maintained until the new valid message is received. If set to Default, the IM1 status, pre-defined by the user in IM1 Default Value cell will be set. A new valid message will replace IM1 Default Value, once the channel recovers.				
IM1 Default Value	0	0	1	1
Setting that defines the IM1 fallback status.				
IM2 to IM8	Cell as for IM1 above			
Note *The IM1 - IM8 settings in the table above are applied the same to the 8 InterMiCOM^{64} commands grouped as Channel 1 as to the 8 InterMiCOM^{64} commands grouped as Channel 2. If IM1 Default Value is set to 0, then IM1 Channel 1, and IM1 Channel 2 will both default to 0.*				

Table 28 - Prot comms/IM64

5 CONTROL AND SUPPORT SETTINGS

The control and support settings are part of the main menu and are used to configure the relays global configuration. It includes submenu settings as below:

- Relay function configuration settings
- Open/close circuit breaker
- CT & VT ratio settings
- Reset LEDs
- Active protection setting group
- Password & language settings
- Circuit breaker control & monitoring settings
- Communications settings
- Measurement settings
- Event & fault record settings
- User interface settings
- Commissioning settings

5.1 System Data

This menu provides information for the device and general status of the relay.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Language	English			
The default language used by the device. Selectable as English, French, German, Spanish.				
Password	****			
Device default password.				
Sys. Fn. Links	0			1
Setting to allow the fixed function trip LED to be self resetting (set to 1 to extinguish the LED after a period of healthy restoration of load current).				
Description	MiCOM P443			
16 character relay description. Can be edited.				
Plant Reference	MiCOM			
Associated plant description and can be edited.				
Model Number	P443?17H??554?K			
Relay model number. This display cannot be altered.				
Serial Number	123456J			
Relay model number. This display cannot be altered.				
Frequency	50 Hz	50Hz or 60Hz		
Relay set frequency. Settable either 50 or 60Hz				
Comms. Level 2				
Displays the conformance of the relay to the Courier Level 2 comms.				
Relay Address 1	255	0	255	1
Sets the first rear port relay address.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Plant Status	0000000000000010			
Displays the circuit breaker plant status.				
Control Status	0000000000000000			
Not used.				
Active Group	1	1	4	1
Displays the active settings group.				
CB Trip/Close	No Operation	No Operation/ Trip/Close		
Supports trip and close commands if enabled in the Circuit Breaker Control menu.				
Software Ref. 1	P443____1__057_K			
Software Ref. 2	P443____1__057_K			
Displays the relay software version including protocol and relay model. Software Ref. 2 is displayed for relay with IEC 61850 protocol only and this will display the software version of the Ethernet card.				
Opto I/P Status	00000000000000000000000000000000			
Display the status of the available opto inputs fitted.				
Relay O/P Status	00000000000000000000000000000000			
Displays the status of all available output relays fitted.				
Alarm Status 1	00000000000000000000000000000000			
32 bit field gives status of first 32 alarms. Includes fixed and user settable alarms.				
Alarm Status 2	00000000000000000000000000000000			
Next 32 alarm status defined.				
Access Level	2			
Displays the current access level.				
Level 0	No password required	Read access to all settings, alarms, event records and fault records		
Level 1	Password 1 or 2 required	As level 0 plus: Control commands, e.g. circuit breaker open/close Reset of fault and alarm conditions, Reset LEDs Clearing of event and fault records		
Level 2	Password 2 required	As level 1 plus: All other settings		
Password Control	2			1
Sets the menu access level for the relay. This setting can only be changed when level 2 access is enabled.				
Password Level 1	****			
Allows user to change password level 1.				
Password Level 2	****			
Allows user to change password level 2.				

Table 29 - System data

5.2 Circuit Breaker Control

The System Checks functionality differs between the P443 and the P446 since the P443 can only control one circuit breaker, whereas the P446 can control two. Accordingly, therefore, the settings are different for the two relays.

5.2.1.1 P443 Circuit Breaker Control

The relay includes the following options for control of a single circuit breaker:

- Local tripping and closing, via the relay menu or hotkeys
- Local tripping and closing, via relay opto-isolated inputs
- Remote tripping and closing, using the relay communications

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
CB Control By	Disabled	Disabled, Local, Remote, Local + Remote, Opto, Opto + local, Opto + Remote, Opto + Remote + local		
This Setting selects the type of circuit breaker control that be used in the logic				
Close Pulse Time	0.5s	0.1s	10s	0.01s
Defines the duration of the close pulse within which the circuit breaker should close when close command is issued. If the circuit breaker fails to close after elapse of this time, a CB close fail alarm (DDB 303) is set.				
Trip Pulse Time	0.5s	0.1s	5s	0.01s
Defines the duration of the trip pulse within which the circuit breaker should trip when manual or protection trip command is issued. If the circuit breaker does not trip within the set Trip Pulse Time, a circuit breaker failed to trip alarm is set.				
Man Close Delay	10s	0.01s	600s	0.01s
This defines the delay time before the close pulse is executed.				
CB Healthy Time	5s	0.01s	9999s	0.01s
A settable time delay included for manual closure with this circuit breaker check. If the circuit breaker does not indicate a healthy condition in this time period following a close command then the relay will lockout and alarm.				
Check Sync. Time	5s	0.01s	9999s	0.01s
A user settable time delay is included for manual closure with check synchronizing. If the check sync. criteria are not satisfied in this time period following a close command the relay will lockout and alarm.				
Lockout Reset	No	No, Yes		
Displays if the Lockout condition has been reset.				
Reset Lockout By	CB Close	User Interface, CB Close		
Setting that determines if a lockout condition will be reset by a manual circuit breaker close command or via the user interface.				
Man Close RstDly	5s	0.1s	600s	0.01s
The manual close time, time delay, that is used to reset a lockout automatically from a manual close.				
Single Pole A/R	Disabled	Disabled or Enabled		
Enable or disable AR for single phase fault types. *Note* *This setting also applies when auto-reclose is configured in 3 pole tripping applications. Even though the trip mode may be 3 pole only, the fact that the initiation was a single phase fault type is memorized.*				
Three Pole A/R	Disabled	Disabled or Enabled		
Enable or disable AR for multi-phase faults.				
Total Reclosures	Data			
Displays the number of successful re-closures.				
Reset Total A/R	No	No, Yes		

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Allows user to reset the auto-reclose counters.				
CB Status Input	52B 1 pole	None, 52A 1 pole, 52B 1 pole, 52A & 52B 1 pole, 52A 3 pole, 52B 3 pole, 52A & 52B 3 pole		
Setting to define the type of circuit breaker contacts that will be used for the circuit breaker control logic. Form A contacts match the status of the circuit breaker primary contacts, form “ are opposite to the breaker status. When 1 pole is selected, individual contacts must be assigned in the Programmable Scheme Logic for phase A, phase B, and phase C. Setting 3 pole means that only a single contact is used, common to all 3 poles.				

Table 30 - P443 circuit breaker control

5.2.1.2 P446 Circuit Breaker Control

The relay includes the following options for control of two circuit breakers:

- Local tripping and closing, via the relay menu or hotkeys
- Local tripping and closing, via relay opto-isolated inputs
- Remote tripping and closing, using the relay communications

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
CB control by	Disabled	Disabled, Local, Remote, Local + Remote, Opto, Opto + local, Opto + Remote, Opto + Remote + local		
This Setting selects the type of circuit breaker control that be used in the logic. This setting is common to both CB1 and CB2. It determines which manual trip and close controls can be used to control both circuit breakers.				
Close Pulse Time	0.5s	0.1s	10s	0.01s
Defines the duration of the close pulse within which CB should close when close command is issued. If CB fails to close after elapse of this time, CB close fail alarm (DDB 303 or 325 for CB1 & CB2 respectively) is set.				
Trip Pulse Time	0.5s	0.1s	5s	0.01s
Defines the duration of the trip pulse within which CB should trip when manual or protection trip command is issued. If CB does not trip within set Trip Pulse Time, CB failed to trip alarm is set.				
Man Close Delay	10s	0.01s	600s	0.01s
This defines the delay time before the close pulse is executed.				
CB Healthy Time	5s	0.01s	9999s	0.01s
A settable time delay included for manual closure of the circuit breaker. If the circuit breaker does not indicate a healthy condition in this time period following a close command then the relay will lockout and alarm. Input DDB (436 & 437) are used for CB1 Healthy & CB2 Healthy respectively to enable CB1 and CB2 closing. If the set time runs out with input DDB (304 or 326 for CB1 & CB2 respectively): CBx Healthy low (= 0), alarm ManCBx Unhealthy is set and operator controlled CBx close sequence is cancelled.				
Check Sync. Time	5s	0.01s	9999s	0.01s
A user settable time delay is included for manual closure with System Check Synchronizing. If the System Check Synchronizing criteria are not satisfied in this time period following a close command the relay will lockout and alarm. Input signals CB1Man SCOK, DDB (1574) and CB2Man SCOK, DDB (1458) from system check logic is used to enable CB Closing by manual control. If set time runs out with input signal CBxMan SCOK low (= 0), alarm Control NoCS CBxManClose (DDB 305 or 327 for CB1 & CB2 respectively) is set and CB close sequence is cancelled.				
Rst CB mon LO By	CB Close	User Interface, CB Close		
This setting is used to decide preferred option to reset of a lockout condition caused by CB monitoring conditions either by a manual circuit breaker close command or via the user interface.				
CB mon LO RstDly	5s	0.1s	600s	0.01s

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
If Rst CB mon LO By is set to CB Close then CB mon LO RstDly timer allows reset of CB lockout state after set time delay.				
CB1 Status Input	52B 1 pole	None, 52A 1 pole, 52B 1 pole, 52A & 52B 1 pole, 52A 3 pole, 52B 3 pole, 52A & 52B 3 pole		
Setting to define the type of circuit breaker contacts that will be used for the circuit breaker control logic. Form A contacts match the status of the circuit breaker primary contacts, form B are opposite to the breaker status. When 1 pole is selected, individual contacts must be assigned in the Programmable Scheme Logic for phase A, phase B, and phase C. Setting 3 pole means that only a single contact is used, common to all 3 poles.				
CB Status Time	5s	0.1s	5s	0.01s
Under healthy conditions the circuit breaker auxiliary contacts will be in opposite states. Should both sets of contacts be open or closed, it indicates that either the contacts, or the wiring, or the circuit breaker are defective and an alarm will be issued after CB Status Time delay. The time delay is set to avoid unwanted operation during normal switching duties.				
CB2 Status Input	52B 1 pole	None, 52A 1 pole, 52B 1 pole, 52A & 52B 1 pole, 52A 3 pole, 52B 3 pole, 52A & 52B 3 pole		
Setting to define the type of circuit breaker contacts that will be used for the circuit breaker control logic. Form A contacts match the status of the circuit breaker primary contacts, form B are opposite to the breaker status. When 1 pole is selected, individual contacts must be assigned in the Programmable Scheme Logic for phase A, phase B, and phase C. Setting 3 pole means that only a single contact is used, common to all 3 poles.				
Res AROK by UI	Enabled	Enabled or Disabled		
If Enabled, this allows the successful auto-reclose signal to be reset by user interface command Reset AROK Ind.				
Res AROK by NoAR	Disabled	Enabled or Disabled		
If Enabled, this allows the successful auto-reclose signal to be reset by temporarily disabling auto-reclosing. Refer to the Operation section (P44y/EN OP) for details of auto-reclose enabling/disabling.				
Res AROK by Ext	Disabled	Enabled or Disabled		
If Enabled, this allows the successful auto-reclose signal (CB1 or CB2) to be reset by activation of the relevant input Ext Rst CB1 AROK or Ext Rst CB2 AROK DDB (1517/1417) mapping in the PSL.				
Res AROK by TDly	Disabled	Enabled or Disabled		
If Enabled, this allows the successful auto-reclose signal to be reset after a time delay as set in the "Res AROK by TDly" setting.				
Res AROK by TDly	1.0s	1.0s	9999s	1.0s
Time delay for the successful auto-reclose signal to reset, if setting Res AROK by TDly is Enabled.				
Res LO by CB IS	Enabled	Enabled or Disabled		
If Enabled, this allows reset of the CB lockout state when the CB is In Service (i.e. CB is closed for time > CB IS Time).				
Res LO by UI	Enabled	Enabled or Disabled		
If Enabled, this allows reset of each CB lockout state by User Interface commands Reset CB1 LO or Reset CB2 LO.				
Res LO by NoAR	Disabled	Enabled or Disabled		
If Enabled, this allows reset of the CB lockout state by temporarily disabling auto-reclosing. Refer to the Operation section (P44y/EN OP) for details of auto-reclose enabling/disabling.				
Res LO by ExtDDB	Disabled	Enabled or Disabled		
If Enabled, this allows the CB lockout state (CB1/CB2) to be reset by activation of the relevant input Rst CB1 Lockout or Rst CB2 Lockout DDBs (446/1422) mapping in the PSL.				
Res LO by TDelay	Disabled	Enabled or Disabled		
If Enabled, this allows the CB lockout state to be reset after a time delay as set in the LO Reset Time.				
LO Reset Time	1.0s	1.0s	9999s	1.0s
Time delay for CB lockout state to be reset, if Res LO by TDelay is Enabled.				

Table 31 - P446 circuit breaker control

5.3 Date and Time

Displays the date and time as well as the battery condition.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Date/Time	Data			
Displays the relay’s current date and time.				
IRIG-B Sync.	Disabled	Disabled or Enabled		
Enable IRIG-B time synchronization.				
IRIG-B Status	Data	Card not fitted/Card failed/ Signal healthy/No signal		
Displays the status of IRIG-B.				
Battery Status	Data			
Displays whether the battery is healthy or not.				
Battery Alarm	Enabled	Enabled or Disabled		
Setting that determines whether an unhealthy relay battery condition is alarmed or not.				
SNTP Status	Data			
Ethernet versions only. Displays information about the SNTP time synchronization status: Disabled, Trying Server 1, Trying Server 2, Server 1 OK, Server 2 OK, No response, or No valid clock.				
LocalTime Enable	Disabled	Disabled/Fixed/Flexible		
Setting to turn on/off local time adjustments. Disabled: No local time zone will be maintained. Time synchronization from any interface will be used to directly set the master clock and all displayed (or read) times on all interfaces will be based on the master clock with no adjustment. Fixed: A local time zone adjustment can be defined using the LocalTime offset setting and all interfaces will use local time except SNTP time synchronization and IEC61850 timestamps. Flexible: A local time zone adjustment can be defined using the LocalTime offset setting and each interface can be assigned to the UTC zone or local time zone with the exception of the local interfaces which will always be in the local time zone and IEC61850/SNTP which will always be in the UTC zone.				
LocalTime Offset	0	-720	720	15
Setting to specify an offset of -12 to +12 hrs in 15 minute intervals for local time zone. This adjustment is applied to the time based on the master clock which is UTC/GMT.				
DST Enable	Disabled	Disabled or Enabled		
Setting to turn on/off daylight saving time adjustment to local time.				
DST Offset	60mins	30	60	30min
Setting to specify daylight saving offset which will be used for the time adjustment to local time.				
DST Start	Last	First, Second, Third, Fourth, Last		
Setting to specify the week of the month in which daylight saving time adjustment starts.				
DST Start Day	Sunday	Monday, Tuesday, Wednesday, Thursday, Friday, Saturday		
Setting to specify the day of the week in which daylight saving time adjustment starts.				
DST Start Month	March	January, February, March, April, May, June, July, August, September, October, November, December		
Setting to specify the month in which daylight saving time adjustment starts.				
DST Start Mins	60min	0	1425	15min
Setting to specify the time of day in which daylight saving time adjustment starts. This is set relative to 00:00 hrs on the selected day when time adjustment is to start.				
DST End	Last	First, Second, Third, Fourth, Last		
Setting to specify the week of the month in which daylight saving time adjustment ends.				
DST End Day	Sunday	Monday, Tuesday, Wednesday, Thursday, Friday, Saturday		

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Setting to specify the day of the week in which daylight saving time adjustment ends.				
DST End Month	October	January, February, March, April, May, June, July, August, September, October, November, December		
Setting to specify the month in which daylight saving time adjustment ends.				
DST End Mins	60	0	1425	15min
Setting to specify the time of day in which daylight saving time adjustment ends. This is set relative to 00:00 hrs on the selected day when time adjustment is to end.				
RP1 Time Zone	Local	UTC or Local		
Setting for the rear port 1 interface to specify if time synchronization received will be local or universal time co-ordinated.				
RP2 Time Zone	Local	UTC or Local		
Setting for the rear port 2 interface to specify if time synchronization received will be local or universal time co-ordinated				
DNPOE Time Zone	Local	UTC or Local		
Setting to specify if time synchronization received will be local or universal time co-ordinate when DNP3.0 protocol is implemented over Ethernet.				
Tunnel Time Zone	Local	UTC or Local		
Setting to specify if time synchronization received will be local or universal time co-ordinate when tunneling courier protocol over Ethernet.				

Table 32 - Date and time

5.4 CT/VT Ratios

The CT/VT ratio settings differ between the P443 and the P446 because of the different number of circuit breakers controlled.

5.4.1.1 P443 CT/VT Ratios

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Main VT Primary	110.0 V	100V	1000 kV	1
Sets the main voltage transformer input primary voltage.				
Main VT Sec'y	110.0 V	80V	140V	1
Sets the main voltage transformer input secondary voltage.				
C/S VT Primary	110.0 V	100V	1000 kV	1
Sets the check sync. voltage transformer input primary voltage.				
C/S VT Secondary	110.0 V	80V	140V	1
Sets the check sync. voltage transformer input secondary voltage.				
Phase CT Primary	1.000A	1A	30kA	1
Sets the phase current transformer input primary current rating.				
Phase CT Sec'y	1A	1A	5A	4
Sets the phase current transformer input secondary current rating.				
SEF CT Primary	1.000A	1A	30kA	1
Sets the sensitive earth fault current transformer input primary current rating.				
SEF CT Secondary	1A	1A	5A	4
Sets the sensitive earth fault current transformer input secondary current rating.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
MComp CT Primary	1.000A	1	30k	1
Sets the primary current rating of the neutral transformer that is located on the parallel line.				
MComp CT Secondary	1A	1A	5A	4
Sets the secondary current rating of the neutral transformer that is located on the parallel line.				
C/S Input	A-N	A-N, B-N, C-N, A-B, B-C, C-A, A-N/1.732, B-N/1.732, C-N/1.732		N/A
Selects the check sync. Input voltage measurement.				
Main VT Location	Line	Line, Bus		N/A
Selects the main voltage transformer location.				
CT Polarity	Standard	Standard or Inverted		
To invert polarity (180°) of the CT.				
SEF CT Polarity	Standard	Standard or Inverted		
To invert polarity (180°) of the SEF CT.				
M CT Polarity	Standard	Standard or Inverted		
To invert polarity (180°) of the M CT.				

Table 33 - P443 CT/VT ratios

5.4.1.2 P446 CT/VT Ratios

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Main VT Primary	110.0 V	100V	1000 kV	1
Sets the main voltage transformer input primary voltage.				
Main VT Sec'y	110.0 V	80V	140V	1
Sets the main voltage transformer input secondary voltage.				
CB1 CS VT Prim'y	110.0 V	100V	1000 kV	1
Sets the System Check Synchronism voltage transformer input primary voltage.				
CB1 CS VT Sec'y	110.0 V	80V	140V	1
Sets the System Check Synchronism voltage transformer input secondary voltage.				
CB2 CS VT Prim'y	110.0 V	100V	1000 kV	1
Sets the System Check Synchronism voltage transformer input primary voltage.				
CB2 CS VT Sec'y	110.0 V	80V	140V	1
Sets the System Check Synchronism voltage transformer input secondary voltage.				
Phase CT Primary	1.000A	1	30k	1
Sets the phase current transformer input primary current rating.				
Phase CT Sec'y	1.000A	1	5	4
Sets the phase current transformer input secondary current rating.				
SEF CT Primary	1.000A	1A	30kA	1
Sets the sensitive earth fault current transformer input primary current rating.				
SEF CT Secondary	1A	1A	5A	4
Sets the sensitive earth fault current transformer input secondary current rating.				
MComp CT Primary	1.000A	1	30k	1
Sets the primary current rating of the neutral transformer that is located on the parallel line.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
MComp CT Sec'y	1A	1A	5A	4
Sets the secondary current rating of the neutral transformer that is located on the parallel line.				
CS Input	A-N	A-N, B-N, C-N, A-B, B-C, C-A		N/A
Selects the System Check Synchronism Input voltage measurement.				
CT1 Polarity	Standard	Standard or Inverted		
To invert polarity (180°) of the CT.				
CT2 Polarity	Standard	Standard or Inverted		
To invert polarity (180°) of the CT2.				
SEF CT Polarity	Standard	Standard or Inverted		
To invert polarity (180°) of the SEF CT.				
M CT Polarity	Standard	Standard or Inverted		
To invert polarity (180°) of the M CT.				
CB1 CS VT PhShft	0 deg	-180 deg	180 deg	5 deg
Phase angle difference between selected phase (C/S Input 0A 0F) of Line VT input and applied CS1 VT input voltage under healthy system conditions.				
CB1 CS VT Mag.	1.0	0.2	3	0.01
Ratio of voltage magnitudes of selected phase (C/S Input 0A 0F) of Line VT input and applied CS1 VT input voltage under healthy system conditions.				
CB2 CS VT PhShft	0 deg	-180 deg	180 deg	5 deg
Phase angle difference between selected phase (C/S Input 0A 0F) of Line VT input and applied CS2 VT input voltage under healthy system conditions.				
CB2 CS VT Mag.	1.0	0.2	3	0.01
Ratio of voltage magnitudes of selected phase (C/S Input 0A 0F) of Line VT input and applied CS2 VT input voltage under healthy system conditions.				

Table 34 - P446 CT/VT ratios

5.5 Record Control

It is possible to disable the reporting of events from all interfaces that supports setting changes. The settings that control the various types of events are in the Record Control column. The effect of setting each to disabled is as follows:

Menu Text	Default Setting	Available Settings
Alarm Event	Enabled	Enabled or Disabled
Disabling this setting means that all the occurrences that produce an alarm will result in no event being generated.		
Relay O/P Event	Enabled	Enabled or Disabled
Disabling this setting means that no event will be generated for any change in logic output state.		
Opto Input Event	Enabled	Enabled or Disabled
Disabling this setting means that no event will be generated for any change in logic input state.		
General Event	Enabled	Enabled or Disabled
Disabling this setting means that no General Events will be generated.		
Fault Rec. Event	Enabled	Enabled or Disabled
Disabling this setting means that no event will be generated for any fault that produces a fault record.		
Maint. Rec. Event	Enabled	Enabled or Disabled
Disabling this setting means that no event will be generated for any occurrence that produces a maintenance record.		
Protection Event	Enabled	Enabled or Disabled
Disabling this setting means that any operation of protection elements will not be logged as an event.		
DDB 31 - 0	11111111111111111111111111111111	
Chooses whether any individual DDBs should be deselected as a stored event, by setting the relevant bit to “0” (zero). Typically used for repetitive recurrent changes such as an Opto input assigned for Minute Pulse clock synchronizing.		
Up to… DDB 1791 - 1760	11111111111111111111111111111111	
As above, for all DDBs through to 1791.		

Table 35 - Record control

5.6 Measurements

Menu Text	Default Settings	Available settings
MEASUREMENT SETUP		
Default Display	Description	Description/Plant Reference/ Frequency/Access Level/3Ph + N Current/3Ph Voltage/Power/Date and Time
This setting can be used to select the default display from a range of options, Note: It is also possible to view the other default displays whilst at the default level using the ← and → keys. However once the 15 minute timeout elapses the default display will revert to that selected by this setting.		
Local Values	Primary	Primary/Secondary
This setting controls whether measured values via the front panel user interface and the front courier port are displayed as primary or secondary quantities.		
Remote Values	Primary	Primary/Secondary
This setting controls whether measured values via the rear communication port are displayed as primary or secondary quantities.		
Measurement Ref.	VA	VA/VB/VC/IA/IB/IC
Using this setting the phase reference for all angular measurements by the relay can be selected.		
Measurement Mode	0	0 to 3 step 1

Menu Text	Default Settings	Available settings
MEASUREMENT SETUP		
This setting is used to control the signing of the real and reactive power quantities; the signing convention used is defined in the Measurements and Recording section (P44y/EN MR).		
Fix Dem. Period	30 minutes	1 to 99 minutes step 1 minute
This setting defines the length of the fixed demand window.		
Roll Sub Period	30 minutes	1 to 99 minutes step 1 minute
These two settings are used to set the length of the window used for the calculation of rolling demand quantities.		
Num. Sub Periods	1	1 to 15 step 1
This setting is used to set the resolution of the rolling sub window.		
Distance Unit*	km	km/miles
This setting is used to select the unit of distance for fault location purposes, Note: The length of the line is preserved when converting from km to miles and vice versa.		
Fault Location*	Distance	Distance/Ohms/% of Line
The calculated fault location can be displayed using one of several options selected using this setting.		
Remote2 Values	Primary	Primary or Secondary
The setting defines whether the values measured via the 2nd Rear Communication port are displayed in primary or secondary terms.		

Table 36 - Measurements

5.7 Communications Settings

The communications settings apply to the rear communications ports only and will depend upon the particular protocol being used. Further details are given in the SCADA communications section (P44y/EN SC).

5.7.1.1 Communications Settings for Courier Protocol

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
COMMUNICATIONS				
RP1 Protocol	Courier			
Indicates the communications protocol that will be used on the rear communications port.				
RP1 Remote Address	255	0	255	1
This cell sets the unique address for the relay such that only one relay is accessed by master station software.				
RP1 Inactivity Timer	15 mins.	1 min.	30 mins.	1 min.
This cell controls how long the relay will wait without receiving any messages on the rear port before it reverts to its default state, including resetting any password access that was enabled.				
RP1 Physical Link	Copper	Copper or Fiber Optic		
This cell defines whether an electrical (copper) or fiber optic connection is being used for communication between the master station and relay. The optional fiber optic communications board will be required If Fiber Optic is to be selected.				
RP1 Port Config.	KBus	KBus or EIA(RS)485		
This cell defines whether an electrical KBus or EIA(RS)485 is being used for communication between the master station and relay.				
RP1 Comms. Mode	IEC60870 FT1.2 Frame	IEC60870 FT1.2 Frame or 10-Bit No Parity		
The choice is either IEC60870 FT1.2 for normal operation with 11-bit modems, or 10-bit no parity.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
RP1 Baud Rate	19200 bits/s	9600 bits/s, 19200 bits/s or 38400 bits/s		
This cell controls the communication speed between relay and master station. It is important that both relay and master station are set at the same speed setting.				

Table 37 - Communications settings for Courier protocol

5.7.1.2 Communications Settings for IEC60870-5-103 Protocol

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
COMMUNICATIONS				
RP1 Protocol	IEC60870-5-103			
Indicates the communications protocol that will be used on the rear communications port.				
RP1 Address	1	0	247	1
This cell sets the unique address for the relay such that only one relay is accessed by master station software.				
RP1 Inactivity Timer	15 mins.	1 min.	30 mins.	1 min.
This cell controls how long the relay will wait without receiving any messages on the rear port before it reverts to its default state, including resetting any password access that was enabled.				
RP1 Baud Rate	19200 bits/s	9600 bits/s or 19200 bits/s		
This cell controls the communication speed between relay and master station. It is important that both relay and master station are set at the same speed setting.				
RP1 Measure't. Period	15s	1s	60s	1s
This cell controls the time interval that the relay will use between sending measurement data to the master station.				
RP1 Physical Link	Copper	Copper or Fiber Optic		
This cell defines whether an electrical EIA(RS)485 or fiber optic connection is being used for communication between the master station and relay. If Fiber Optic is selected, the optional fiber optic communications board will be required.				
RP1 CS103 Blocking	Disabled	Disabled, Monitor Blocking, or Command Blocking		
There are three settings associated with this cell: Disabled No blocking selected. Monitor Blocking When the monitor blocking DDB Signal is active high, either by energizing an opto input or control input, reading of the status information and disturbance records is not permitted. When in this mode the relay returns a termination of general interrogation message to the master station. Command Blocking When the command blocking DDB signal is active high, either by energizing an opto input or control input, all remote commands will be ignored (i.e. CB Trip/Close, change setting group etc.). When in this mode the relay returns a negative acknowledgement of command message to the master station.				

Table 38 - Communications settings for IEC60870-5-103 protocol

5.7.1.3 Communications Settings for DNP3.0 Protocol

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
COMMUNICATIONS				
RP1 Protocol	DNP3.0			
Indicates the communications protocol that will be used on the rear communications port.				
RP1 Address	3	0	65519	1
This cell sets the unique address for the relay such that only one relay is accessed by master station software.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
RP1 Baud Rate	19200 bits/s	1200 bits/s, 2400 bits/s, 4800 bits/s, 9600 bits/s, 19200 bits/s or 38400 bits/s		
This cell controls the communication speed between relay and master station. It is important that both relay and master station are set at the same speed setting.				
RP1 Parity	None	Odd, Even or None		
This cell controls the parity format used in the data frames. It is important that both relay and master station are set with the same parity setting.				
RP1 Physical Link	Copper	Copper or Fiber Optic		
This cell defines whether an electrical EIA(RS) 485 or fiber optic connection is being used for communication between the master station and relay. If Fiber Optic is selected, the optional fiber optic communications board will be required.				
RP1 Time Sync.	Disabled	Disabled or Enabled		
If set to Enabled the DNP3.0 master station can be used to synchronize the time on the relay. If set to Disabled either the internal free running clock, or IRIG-B input are used.				
Meas Scaling.	Primary	Primary, Secondary or Normalized		
Setting to report analog values in terms of primary, secondary or normalized (with respect to the CT/VT ratio setting) values.				
Message Gap (ms)	ϕ	0	50	1
This setting allows the master station to have an interframe gap.				
DNP3.0 Need Time	10 mins	1 min	30 mins	1 min
The duration of time waited before requesting another time sync. from the master.				
DNP3.0 App Fragment	2048	100	2048	1
The maximum message length (application fragment size) transmitted by the relay.				
DNP App Timeout	2s	1s	120s	1s
Duration of time waited, after sending a message fragment and awaiting a confirmation from the master.				
DNP SBO Timeout	10s	1s	10s	1s
Duration of time waited, after receiving a select command and awaiting an operate confirmation from the master.				
DNP Link Timeout	60s	0.1s	60s	0.1s
Duration of time that the relay will wait for a Data Link Confirm from the master. A value of 0 means data link support disabled and 1 to 120 seconds is the timeout setting.				

Table 39 - Communications settings for DNP3.0 protocol

5.7.2 Communications Settings for Ethernet Port - IEC61860

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
NIC Protocol	IEC61850			
Indicates that IEC61850 will be used on the rear Ethernet port.				
NIC MAC Address	Ethernet MAC Address			
Indicates the MAC address of the rear Ethernet port.				
NIC Tunl Timeout	5 mins	1 min	30 mins	1 min
Duration of time waited before an inactive tunnel to MiCOM S1 is reset.				
NIC Link Report		Alarm	Alarm, Event, None	
Configures how a failed/unfitted network link (copper or fiber) is reported: Alarm - An alarm is raised for a failed link. Event - An event is logged for a failed link. None - Nothing reported for a failed link.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
NIC Link Timeout	60s	0.1s	60s	0.1s
Duration of time waited, after failed network link is detected, before communication by the alternative media interface is attempted.				

Table 40 - Communications settings for Ethernet port - IEC61860

5.7.3 Communications Settings for Ethernet Port - DNP3.0

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
NIC Protocol	DNP3.0			
Indicates that DNP3.0 will be used on the rear Ethernet port.				
IP Address	0.0.0.0			
Indicates the IP address of the relay.				
Subnet Mask	0.0.0.0			
Indicates the Subnet address.				
NIC MAC Address	*Ethernet MAC Address*			
Indicates the MAC address of the rear Ethernet port.				
Gateway				
Indicates the Gateway address.				
DNP Time Sync.	Disabled	Disabled or Enabled		
If set to Enabled the DNP3.0 master station can be used to synchronize the time on the relay. If set to Disabled either the internal free running clock, or IRIG-B input are used.				
NIC Tunl Timeout	5 mins	1 min	30 mins	1 min
Duration of time waited before an inactive tunnel to MiCOM S1 is reset.				
NIC Link Report	Alarm	Alarm, Event, None		
Configures how a failed/unfitted network link (copper or fiber) is reported: Alarm An alarm is raised for a failed link Event An event is logged for a failed link None Nothing reported for a failed link				
NIC Link Timeout	60s	0.1s	60s	0.1s
Duration of time waited, after failed network link is detected, before communication by the alternative media interface is attempted.				
SNTP PARAMETERS				
SNTP Server 1	SNTP Server 1 address			
Indicates the SNTP Server 1 Address.				
SNTP Server 2	SNTP Server 1 address			
Indicates the SNTP Server 2 Address				
SNTP Poll Rate	64s	64s	1024s	1s
Duration of SNTP poll rate in seconds.				
DNP3.0 Need Time	10 mins	1 min	30 mins	1 min
The duration of time waited before requesting another time sync from the master.				
DNP App Fragment	2048	100	2048	1
The maximum message length (application fragment size) transmitted by the relay.				
DNP App Timeout	2s	1s	120s	1s

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Duration of time waited, after sending a message fragment and awaiting a confirmation from the master.				
DNP SBO Timeout	10s	1s	10s	1s
Duration of time waited, after receiving a select command and awaiting an operate confirmation from the master.				

Table 41 - Communications settings for Ethernet port - DNP3.0

5.7.3.1 Rear Port 2 Connection Settings

The settings shown are those configurable for the second rear port which is only available with the Courier protocol.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
COMMUNICATIONS				
RP2 Protocol	Courier			
Indicates the communications protocol that will be used on the rear communications port.				
RP2 Port Config.	EIA(RS)232	EIA(RS)232, EIA(RS)485 or KBus		
This cell defines whether an electrical EIA(RS)232, EIA(RS)485 or KBus is being used for communication.				
RP2 Comms. Mode	IEC60870 FT1.2 Frame	IEC60870 FT1.2 Frame or 10-Bit No Parity		
The choice is either IEC60870 FT1.2 for normal operation with 11-bit modems, or 10-bit no parity.				
RP2 Address	255	0	255	1
This cell sets the unique address for the relay such that only one relay is accessed by master station software.				
RP2 Inactivity Timer	15 mins.	1 mins.	30 mins.	1 min.
This cell controls how long the relay will wait without receiving any messages on the rear port before it reverts to its default state, including resetting any password access that was enabled.				
RP2 Baud Rate	19200 bits/s	9600 bits/s, 19200 bits/s or 38400 bits/s		
This cell controls the communication speed between relay and master station. It is important that both relay and master station are set at the same speed setting.				

Table 42 - Rear port 2 connection settings

5.8 Commissioning Tests

There are menu cells which allow the status of the opto-isolated inputs, output relay contacts, internal Digital Data Bus (DDB) signals and user-programmable LEDs to be monitored. Additionally there are cells to test the operation of the output contacts, user-programmable LEDs and, where available, the auto-reclose cycles.

Menu Text	Default Setting	Available Settings
COMMISSION TESTS		
Opto I/P Status	000000000000000000000000	
This menu cell displays the status of the available relay’s opto-isolated inputs as a binary string, a 1 indicating an energized opto-isolated input and a 0 a de-energized one		
Relay O/P Status	0000000000000000	
This menu cell displays the status of the digital data bus (DDB) signals that result in energization of the available output relays as a binary string, a ‘1’ indicating an operated state and 0 a non-operated state. When the Test Mode cell is set to Enabled the Relay O/P Status cell does not show the current status of the output relays and hence can not be used to confirm operation of the output relays. Therefore it will be necessary to monitor the state of each contact in turn.		
Test Port Status	00000000	
This menu cell displays the status of the eight digital data bus (DDB) signals that have been allocated in the Monitor Bit cells.		
Monitor Bit 1	1060 (LED 1)	0 to 1791 See PSL section for details of digital data bus signals
The eight Monitor Bit cells allow the user to select the status of which digital data bus signals can be observed in the Test Port Status cell or via the monitor/download port.		
Monitor Bit 8	1074 (LED 8)	0 to 1791
The eight Monitor Bit cells allow the user to select the status of which digital data bus signals can be observed in the Test Port Status cell or via the monitor/download port.		
Test Mode	Disabled	Disabled, Test Mode, Contacts Blocked
The Test Mode menu cell is used to allow secondary injection testing to be performed on the relay without operation of the trip contacts. It also enables a facility to directly test the output contacts by applying menu controlled test signals. To select test mode the Test Mode menu cell should be set to Test Mode, which takes the relay out of service and blocks operation of output contacts and maintenance, counters. It also causes an alarm condition to be recorded and the yellow Out of Service LED to illuminate and an alarm message Prot’n. Disabled is given. This also freezes any information stored in the Circuit Breaker Condition column and in IEC60870-5-103 builds changes the Cause of Transmission, COT, to Test Mode. To enable testing of output contacts the Test Mode cell should be set to Contacts Blocked. This blocks the protection from operating the contacts and enables the test pattern and contact test functions which can be used to manually operate the output contacts. Once testing is complete the cell must be set back to Disabled to restore the relay back to service.		
Test Pattern	00000000000000000000000000000000	0 = Not Operated 1 = Operated
This cell is used to select the output relay contacts that will be tested when the Contact Test cell is set to Apply Test.		
Contact Test	No Operation	No Operation, Apply Test, Remove Test
When the Apply Test command in this cell is issued the contacts set for operation (set to 1) in the Test Pattern cell change state. After the test has been applied the command text on the LCD will change to No Operation and the contacts will remain in the Test State until reset issuing the Remove Test command. The command text on the LCD will again revert to No Operation after the Remove Test command has been issued. *Note* *When the Test Mode cell is set to Enabled the Relay O/P Status cell does not show the current status of the output relays and hence can not be used to confirm operation of the output relays. Therefore it will be necessary to monitor the state of each contact in turn.*		
Test LEDs	No Operation	No Operation Apply Test

Menu Text	Default Setting	Available Settings
COMMISSION TESTS		
When the Apply Test command in this cell is issued the eighteen user-programmable LEDs will illuminate for approximately 2 seconds before they extinguish and the command text on the LCD reverts to No Operation.		
Test Auto-reclose	No Operation	No Operation, Trip 3 Pole, Trip Pole A, Trip Pole B, Trip Pole C
This is a command used to simulate a single pole or three phase tripping to test the Auto-reclose cycle.		
Static Test	Disabled	Disabled or Enabled
When Static test is Enabled, delta phase selectors and the delta directional line are bypassed to allow the user to test the relay with older injection test sets that are incapable of simulating real dynamic step changes in current and voltage. Resulting trip times will be slower, as extra filtering of distance comparators is also switched-in.		
Test Loopback	Disabled	Disabled, Internal, External
Setting that allows communication loopback testing. This is only applicable for InterMiCOM^{64}.		
IM64 TestPattern	0000000000000000	
This cell is used to set the DDB signals included in the User Defined Inter-Relay Commands IM64 when the IM64 Test Mode cell is set to Enable.		
IM64 Test Mode	Disabled	Disabled or Enabled
When the Enable command in this cell is issued the DDB set for operation (set to 1) in the Test Pattern cell change state.		
Red LED Status	000000000000000000	
This cell is an eighteen bit binary string that indicates which of the user-programmable LEDs on the relay are illuminated with the Red LED input active when accessing the relay from a remote location, a 1 indicating a particular LED is lit and a 0 not lit.		
Green LED Status	000000000000000000	
This cell is an eighteen bit binary string that indicates which of the user-programmable LEDs on the relay are illuminated with the Green LED input active when accessing the relay from a remote location, a 1 indicating a particular LED is lit and a 0 not lit.		
DDB 31 - 0	00000000000000000000001000000000	
Displays the status of DDB signals 0-31.		
… DDB 1791 - 1760	00000000000000000000000000000000	
... For monitoring all DDB signals up to 1791.		

Table 43 - Commissioning tests

5.9 Circuit Breaker Condition Monitor Setup

Table 44, detailing the options available for the Circuit Breaker condition monitoring for the P443, is taken from the relay menu. It includes the setup of the ruptured current facility and those features that can be set to raise an alarm, or lockout the CB.

For the P446 there is a similar set of settings duplicated for the second circuit breaker controlled. Although the menu text differs slightly to reflect the monitoring of two circuit breakers (CB1 and CB2), in all other respects the settings are the same.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Broken I^	2	1	2	0.1
This sets the factor to be used for the cumulative I^ counter calculation that monitors the cumulative severity of the duty placed on the interrupter. This factor is set according to the type of Circuit Breaker used.				
I^ Maintenance	Alarm Disabled	Alarm Disabled or Alarm Enabled		
Setting which determines if an alarm will be raised or not when the cumulative I^ maintenance counter threshold is exceeded.				
I^ Maintenance	1000In^	1In^	25000In^	1In^
Setting that determines the threshold for the cumulative I^ maintenance counter monitors.				

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
I^ Lockout	Alarm Disabled	Alarm Disabled or Alarm Enabled		
Setting which determines if an alarm will be raised or not when the cumulative I^lockout counter threshold is exceeded.				
I^ Lockout	2000In^	1In^	25000In^	1In^
Setting that determines the threshold for the cumulative I^ lockout counter monitor. Set that should maintenance not be carried out, the relay can be set to lockout the auto-reclose function on reaching a second operations threshold.				
No CB Ops. Maint.	Alarm Disabled	Alarm Disabled or Alarm Enabled		
Setting to activate the number of circuit breaker operations maintenance alarm.				
No CB Ops. Maint.	10	1	10000	1
Sets the threshold for number of circuit breaker operations maintenance alarm, indicating when preventative maintenance is due.				
No CB Ops. Lock	Alarm Disabled	Alarm Disabled or Alarm Enabled		
Setting to activate the number of circuit breaker operations lockout alarm.				
No CB Ops. Lock	20	1	10000	1
Sets the threshold for number of circuit breaker operations lockout. The relay can be set to lockout the auto-reclose function on reaching a second operations threshold.				
CB Time Maint.	Alarm Disabled	Alarm Disabled or Alarm Enabled		
Setting to activate the circuit breaker operating time maintenance alarm.				
CB Time Maint.	0.1s	0.005s	0.5s	0.001s
Setting for the circuit operating time threshold which is set in relation to the specified interrupting time of the circuit breaker.				
CB Time Lockout	Alarm Disabled	Alarm Disabled or Alarm Enabled		
Setting to activate the circuit breaker operating time lockout alarm.				
CB Time Lockout	0.2s	0.005s	0.5s	0.001s
Setting for the circuit breaker operating time threshold which is set in relation to the specified interrupting time of the circuit breaker. The relay can be set to lockout the auto-reclose function on reaching a second operations threshold.				
Fault Freq. Lock	Alarm Disabled	Alarm Disabled or Alarm Enabled		
Enables the excessive fault frequency alarm.				
Fault Freq. Count	10	1	9999	1
Sets a circuit breaker frequent operations counter that monitors the number of operations over a set time period.				
Fault Freq. Time	3600s	0s	9999s	1s
Sets the time period over which the circuit breaker operations are to be monitored. Should the set number of trip operations be accumulated within this time period, an alarm can be raised. Excessive fault frequency/trips can be used to indicate that the circuit may need maintenance attention (e.g. Tree-felling or insulator cleaning).				

Table 44 - Circuit breaker condition monitor setup

5.10 Opto Configuration

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
OPTO CONFIG.				
Global Nominal V	24 - 27	24 - 27, 30 - 34, 48 - 54, 110 - 125, 220 - 250, Custom		
Sets the nominal battery voltage for all opto inputs by selecting one of the five standard ratings in the Global Nominal V settings. If Custom is selected then each opto input can individually be set to a nominal voltage value.				
Opto Input 1	24 - 27	24 - 27, 30 - 34, 48 - 54, 110 - 125, 220 - 250		
Each opto input can individually be set to a nominal voltage value if custom is selected for the global setting.				
Opto Input 2 - 24	24 - 27	24 - 27, 30 - 34, 48 - 54, 110 - 125, 220 - 250		
Each opto input can individually be set to a nominal voltage value if custom is selected for the global setting. The number of inputs may be up to 24, depending on MiCOM P443/P446 model and I/O configuration.				
Opto Filter Cntl.	1111 1111 1111 1111 1011 0111 1111 1011			
Selects each input with a pre-set filter of ½ cycle that renders the input immune to induced noise on the wiring. The number of available bits may be 16, 24 or 32, depending on the I/O configuration.				
Characteristics	Standard 60% - 80%	Standard 60% - 80%, 50% - 70%		
Selects the pick-up and drop-off characteristics of the optos. Selecting the standard setting means they nominally provide a Logic 1 or On value for Voltages ≥80% of the set lower nominal voltage and a Logic 0 or Off value for the voltages ≤60% of the set higher nominal voltage.				

Table 45 - Opto configuration

5.11 Control Inputs

The control inputs function as software switches that can be set or reset either locally or remotely. These inputs can be used to trigger any function that they are connected to as part of the PSL. The setting is not visible if **Control Inputs** are set invisible under the **CONFIGURATION** column.

Menu Text	Default Setting	Setting Range	Step Size
CONTROL INPUTS			
Ctrl I/P Status	00000000000000000000000000000000		
Cell that is used to set (1) and reset (0) the selected Control Input by simply scrolling and changing the status of selected bits. This command will be then recognized and executed in the PSL. Alternatively, each of the 32 Control input can also be set and reset using the individual menu setting cells as follows:			
Control Input 1	No Operation	No Operation or Set or Reset	
Setting to allow Control Inputs 1 set/reset.			
Control Input 2 to 32	No Operation	No Operation or Set or Reset	
Cell as for Control Input 1			

Table 46 - Control inputs

5.12 Control Input Configuration

Instead of operating the control inputs as described in the above section, they could also be set to perform a pre-defined control function. This is achieved by mapping in the Hotkey menu. The operating mode for each of the 32 Control Inputs can be set individually.

Menu Text	Default Setting	Setting Range	Step Size
CTRL I/P CONFIG.			
Hotkey Enabled	11111111111111111111111111111111		
Setting to allow the control inputs to be individually assigned to the Hotkey menu by setting 1 in the appropriate bit in the Hotkey Enabled cell. The hotkey menu allows the control inputs to be set, reset or pulsed without the need to enter the CONTROL INPUTS column			
Control Input 1	Latched	Latched, Pulsed	
Configures the control inputs as either latched or pulsed. A latched control input will remain in the set state until a reset command is given, either by the menu or the serial communications. A pulsed control input, however, will remain energized for 10ms after the set command is given and will then reset automatically (i.e. no reset command required).			
Ctrl Command 1	Set/Reset	Set/Reset, In/Out, Enabled/Disabled, On/Off	
Allows the SET/RESET text, displayed in the hotkey menu, to be changed to something more suitable for the application of an individual control input, such as ON/OFF, IN/OUT etc.			
Control Input 2 to 32	Latched	Latched, Pulsed	
Configures the control inputs as either latched or pulsed.			
Ctrl Command 2 to 32	Set/Reset	Set/Reset, In/Out, Enabled/Disabled, On/Off	
Allows the SET/RESET text, displayed in the hotkey menu, to be changed to something more suitable for the application of an individual control input, such as ON/OFF, IN/OUT etc.			

Table 47 - Control input configuration

5.13 Function Keys

Menu Text	Default Setting	Setting Range		Step Size
		Min.	**Max.**	
FUNCTION KEYS				
Fn. Key Status	0000000000			
Displays the status of each function key.				
Fn. Key 1 Status	Unlock/Enable	Disable, Lock, Unlock/Enable		
Setting to activate function key. The Lock setting allows a function key output that is set to toggle mode to be locked in its current active state.				
Fn. Key 1 Mode	Toggle	Toggle, Normal		
Sets the function key in toggle or normal mode. In Toggle mode, a single key press will set/latch the function key output as high or low in programmable scheme logic. This feature can be used to enable/disable relay functions. In the Normal mode the function key output will remain high as long as key is pressed.				
Fn. Key 1 Label	Function Key 1			
Allows the text of the function key to be changed to something more suitable for the application.				
Fn. Key 2 to 10 Status	Unlock/Enable	Disable, Lock, Unlock/Enable		
Setting to activate function key. The Lock setting allows a function key output that is set to toggle mode to be locked in its current active position.				
Fn. Key 2 to 10 Mode	Toggle	Toggle, Normal		

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
Sets the function key in toggle or normal mode. In Toggle mode, a single key press will set/latch the function key output as high or low in programmable scheme logic. This feature can be used to enable/disable relay functions. In the Normal mode the function key output will remain high as long as key is pressed.				
Fn. Key 2 to 10 Label	Function Key 2 to 10			
Allows the text of the function key to be changed to something more suitable for the application.				

Table 48 - Function keys

5.14 IED Configurator (for IEC 61850 Configuration)

The contents of the IED CONFIGURATOR column are mostly data cells, displayed for information but not editable. To edit the configuration use the IED Configurator tool in MiCOM S1.

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
IED CONFIGURATOR				
Switch Conf.Bank	No Action	No Action, Switch Banks		
Setting which allows the user to switch between the current configuration, held in the Active Memory Bank (and partly displayed below), to the configuration sent to and held in the Inactive Memory Bank.				
Active Conf.Name	Data			
The name of the configuration in the Active Memory Bank, usually taken from the SCL file.				
Active Conf.Rev	Data			
Configuration Revision number of the configuration in the Active Memory Bank, usually taken from the SCL file.				
Inact.Conf.Name	Data			
The name of the configuration in the Inactive Memory Bank, usually taken from the SCL file.				
Inact.Conf.Rev	Data			
Configuration Revision number of the configuration in the Inactive Memory Bank, usually taken from the SCL file.				
IP PARAMETERS				
IP Address	Data			
Displays the unique network IP address that identifies the relay.				
Subnet Mask	Data			
Displays the sub-network that the relay is connected to.				
Gateway	Data			
Displays the IP address of the gateway (proxy) that the relay is connected to, if any.				
SNTP PARAMETERS				
SNTP Server 1	Data			
Displays the IP address of the primary SNTP server.				
SNTP Server 2	Data			
Displays the IP address of the secondary SNTP server.				
IEC61850 SCL				
IED Name	Data			
8 character IED name, which is the unique name on the IEC 61850 network for the IED, usually taken from the SCL file.				
IEC 61850 GOOSE				
GoID	Data			

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
64 character GOOSE Identifier, used for naming the published GOOSE message. Default GoID is TEMPLATESystem/LLN0$GO$gcbST.				
GoEna	Disabled	Disabled, Enabled		
Setting to enable GOOSE publisher settings.				
Test Mode	Disabled	Disabled, Pass Through, Forced		
The Test Mode cell allows the test pattern to be sent in the GOOSE message, for example for testing or commissioning. When Disabled is selected, the test flag is not set. When Pass Through is selected, the test flag is set, but the data in the GOOSE message is sent as normal. When Forced is selected, the test flag is set, and the data sent in the GOOSE message is as per the VOP Test Pattern setting below. Once testing is complete the cell must be set back to Disabled to restore the GOOSE scheme back to normal service.				
VOP Test Pattern	0x00000000	0x00000000	0xFFFFFFFF	1
The 32 bit test pattern applied in Forced test mode.				
Ignore Test Flag	No	No, Yes		
When set to Yes, the test flag in the subscribed GOOSE message is ignored, and the data treated as normal.				

Table 49 - IED configurator (for IEC 61850 configuration)

5.15 Control Input Labels

Menu Text	Default Setting	Setting Range	Step Size
CTRL I/P LABELS			
Control Input 1	Control Input 1	16 Character Text	
Setting to change the text associated with each individual control input. This text will be displayed when a control input is accessed by the hotkey menu, or it can be displayed in the programmable scheme logic.			
Control Input 2 to 32	Control Input 2 to 32	16 Character Text	
Setting to change the text associated with each individual control input. This text will be displayed when a control input is accessed by the hotkey menu, or it can be displayed in the programmable scheme logic.			

Table 50 - Control Input Labels

5.16 Direct Access (Breaker Control and “Hotkeys”)

The Direct Access keys are the **0** and **1** keys situated directly below the LCD display. The user may assign the function of these two keys, to signal direct commands into the PSL logic. Two modes of use exist:

- Tripping and Closing commands to the circuit breaker
- **Hotkey** functions, whereby a mini menu of frequently required commands and operations is accessed. Operators can then easily access the required command, without needing to navigate the full relay menu.

Menu Text	Default Setting	Setting Range	Step Size
CONFIGURATION			
Direct Access	Enabled	Disabled, Enabled, Hotkey only, or CB Ctrl Only	
The front direct access keys that are used as a short cut function of the menu may be: Disabled no function visible on the LCD Enabled all control functions mapped to the Hotkeys and Control Trip/Close are available Hotkey Only only control functions mapped to the Hotkeys are available on the LCD CB Ctrl Only only Control Trip/Control Close command will appear on the relay’s LCD			

Table 51 - Direct access (breaker control and “hotkeys”)

6 DISTURBANCE RECORDER SETTINGS (OSCILLOGRAPHY)

Note	*The disturbance recorder settings were changed with Software Version B0 and again with D0. Therefore models with B0 or D0 software may have different settings to previous models. The D0 settings are shown below.*

The disturbance recorder settings include the record duration and trigger position, selection of analog and digital signals to record, and the signal sources that trigger the recording.

The "**DISTURBANCE RECORDER**" menu column is shown in Table 52:

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
DISTURB. RECORDER				
Duration	1.5 s	0.1s	10.5 s	0.01s
This sets the overall recording time.				
Trigger Position	33.3%	0	100.0%	0.1%
This sets the trigger point as a percentage of the duration. For example, the default settings show that the overall recording time is set to 3.0s with the trigger point being at 33.3% of this, giving 1s pre-fault and 1s post fault recording times.				
Trigger Mode	Single	Single or Extended		
If set to single mode, if a further trigger occurs whilst a recording is taking place, the recorder will ignore the trigger. However, if this has been set to Extended, the post trigger timer will be reset to zero, thereby extending the recording time.				
Analog. Channel 1	VA	IA, IB, IC, IN, IN Sensitive, VA, VB, VC, IM and V Checksync (P443 and P446) and IA2, IB2, IC2, IN2, V Checksync2 (only for P446)		
Selects any available analog input to be assigned to this channel (including derived IN residual current).				
Analog. Channel 2	VB	As above		
Analog. Channel 3	VC	As above		
Analog. Channel 4	IA	As above		
Analog. Channel 5	IB	As above		
Analog. Channel 6	IC	As above		
Analog. Channel 7	IN	As above		
Analog. Channel 8	IN Sensitive	As above		
Digital Inputs 1 to 128	Relays 1 to 14(32) and Optos 1 to 16(24)	Any O/P Contact, Any Opto Inputs, or Internal Digital Signals		
The digital channels may monitor any of the opto isolated inputs or output contacts, in addition to a number of internal relay digital signals, such as protection starts, LEDs etc.				
Inputs 1 to 32 Trigger	No Trigger except Dedicated Trip Relay 3 operation which are set to Trigger L/H	No Trigger, Trigger L/H, Trigger H/L		
Any of the digital channels may be selected to trigger the disturbance recorder on either a low to high or a high to low transition.				
Analog. Channel 9	V Checksync	As above		
Analog. Channel 10	IM (P443) IA2 (P446)	As above		
Analog. Channel 11	IN (P443) IB2 (P446)	As above		
Analog. Channel 12	IN (P443) IC2 (P446)	As above		

Table 52 - Disturbance recorder

Notes:

OPERATION

CHAPTER 5

Date:	02/2013
Hardware Suffix:	M
Software Version:	D0
Connection Diagrams:	10P44303 (SH 01 and 03) 10P44304 (SH 01 and 03) 10P44305 (SH 01 and 03) 10P44306 (SH 01 and 03) 10P44600 10P44601 (SH 1 to 2) 10P44602 (SH 1 to 2) 10P44603 (SH 1 to 2)

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1 OPERATION OF INDIVIDUAL PROTECTION FUNCTIONS

The following sections detail the individual protection functions.

1.1 Phase Fault Distance Protection

The MiCOM P443/P446 has 5 zones of phase fault protection. It is possible to set all zones either with quadrilateral (polygon) characteristics, or with mho circles. Each zone can be set independently to be permanently disabled or permanently enabled.

The impedance plot Figure 1 shows the characteristic when set for mho operation. The characteristic drawn for illustration is based on the default distance settings without dynamic expansion.

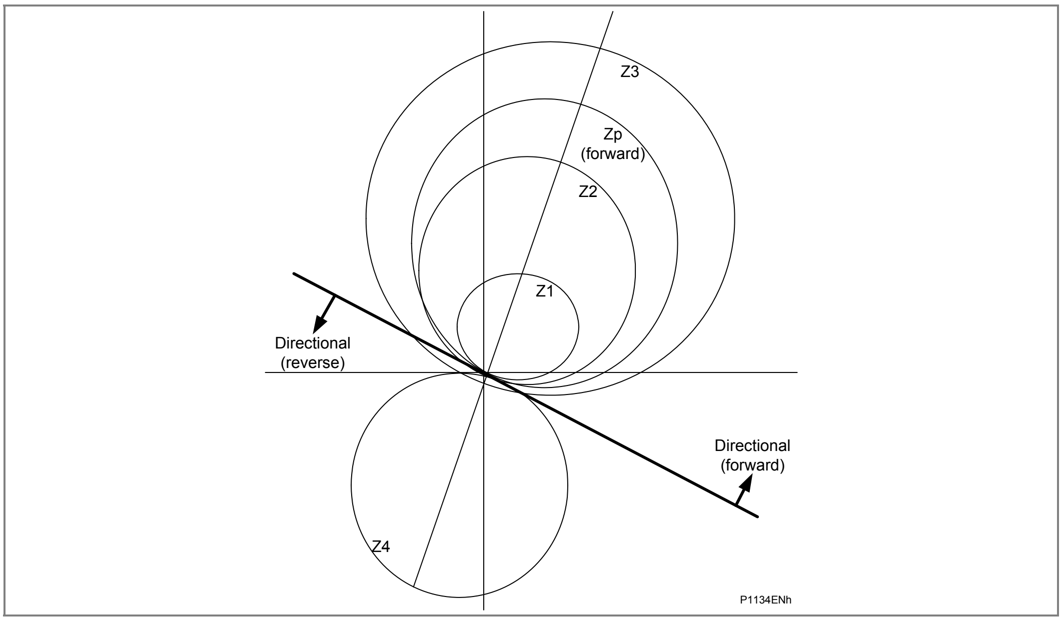


Figure 1 - Phase fault Mho characteristics

The protection elements are directionalized as follows:

Zones 1, 2 and 3	Directional forward zones, as used in conventional three zone distance schemes.

Note *Zone 1 can be extended to Zone 1X when required in zone 1 extension schemes.*

Zone P	Programmable directionality. Selectable as a directional forward or reverse zone.
Zone 4	Directional reverse zone.

1.2 Earth Fault Distance Protection (Optional)

The MiCOM P443/P446 has 5 zones of earth (ground) fault protection. It is also possible to set all zones either with quadrilateral characteristics, or with mho circles. The choice of mho or quadrilateral is independent of the general characteristic selection for the phase fault elements. Each zone can be set independently to be permanently disabled, permanently enabled or enabled in case of protection communication channel fail.

All earth fault distance elements are directionalized as per the phase fault elements, and use residual compensation of the corresponding phase fault reach. The impedance plot Figure 2 adds the characteristics when set for quadrilateral operation.

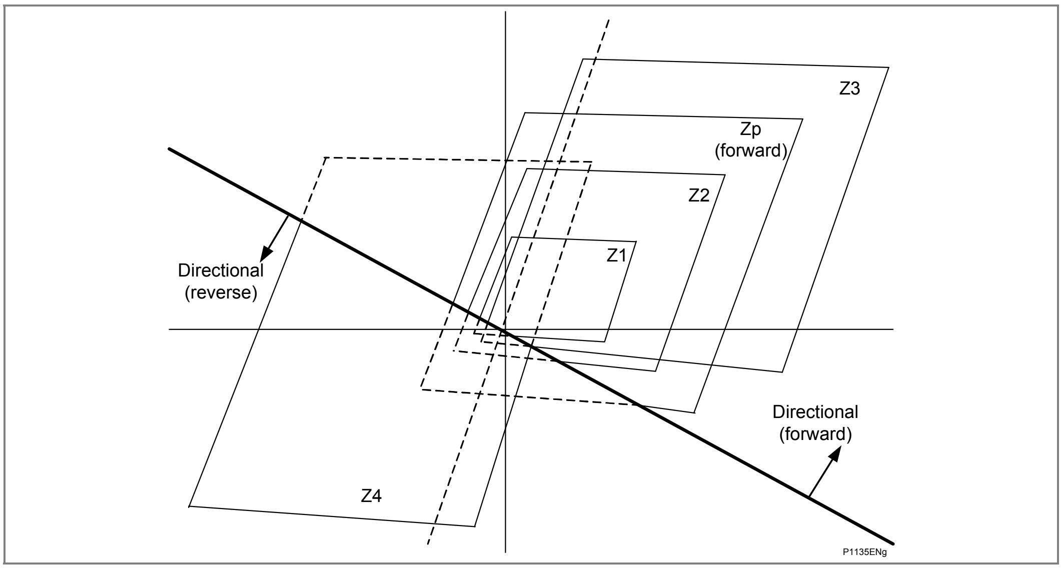


Figure 2 - Earth fault quadrilateral characteristics

1.3 Distance Protection Tripping Decision

For the MiCOM P443/P446, five conditions would generally need to be satisfied in order for a correct relay trip to result. These are:

- The phase selector needs to identify the faulted phases, and ensure that only the correct distance measuring zones may proceed to issue a trip. Possible phase selections are AN, BN, CN, AB, BC, CA, ABC. For double phase to ground faults, the selection is AB, BC or CA, with N (neutral) just for indication only.
- The loop current for the selected phase-ground or phase-phase loop must exceed the minimum sensitivity for the tripping zone. By default, this sensitivity is 5%In for ground faults, and both of the faulted phases must exceed 5%In for phase-phase faults. The user may raise this minimum sensitivity if required, but this is not normally done.
- The faulted phase impedance must appear within a tripping (measuring) zone, corresponding to the phase selection. Five independent zones of protection are provided. The tripping zones are mho circles or quadrilateral, and selected independently for phase, and ground faults. The ground fault distance elements require compensation for the return impedance, this residual compensation modifies the replica impedance for each zone. Under conditions were a parallel line is present the relay can compensate for the mutual coupling between the lines; this adjusts the replica impedance in the same way as the residual compensated based on the current in the parallel line. The reach setting Z for ground fault mho and quadrilateral elements is determined as follows:

$$Z = Z_1 + [(I_{res} / I_P) \times Z_{res}] + [(I_{mut} / I_P) \times Z_{mut}]$$

Where:

Z_1	is the positive sequence reach setting
I_P	is the current in the faulted phase
I_{res}	is the residual current (= $Ia + Ib + Ic$)
Z_{res}	is the residual impedance (= $(Z_0-Z_1)/3$) = $K_{res} \times Z_1$
I_{mut}	is the residual current in the parallel line
Z_{mut}	is the mutual compensating impedance

- For directional zones within the relay (Zone 1, P, 2, 4 and Z3 if set directional), the delta directional line must be in agreement with the tripping zone. For example, zone 1 is a forward directional zone, and must not trip for reverse faults behind the relay location. A zone 1 trip will only be permitted if the directional line issues a "**forward**" decision. The converse will be true for zone 4, which is reverse-looking and this needs a reverse decision by the directional line. If the delta directional cannot make a decision then conventional direction lines are used.
- The set time delay for the measuring zone must expire, with the fault impedance measured inside the zone characteristic for the duration. In general, Zone 1 has no time delay ("**instantaneous**"), all other zones have time delays. Where channel-aided distance schemes are used, the time delay tZ2 for overreaching Zone 2 may be bypassed under certain conditions.

In order to achieve fast, sub-cycle operation, the phase selection, measuring zones and directional line algorithms run in parallel, with their outputs gated in an AND configuration. This avoids sequential measurement which would slow the operation of the relay.

1.4 Phase Selection

Phase selection is the means by which the relay is able to identify exactly which phase are involved in the fault and allow the correct measuring zones to trip.

Operation of the distance elements, is controlled by the Superimposed Current Phase Selector. Only elements associated with the fault type selected by the phase selector are allowed to operate during a period of two cycles following the phase selection. If no such element operates, all elements are enabled for the following 5 cycles, before the phase selector returns to its quiescent state.

Operation of an enabled distance element, during the two cycle or 5 cycle period, causes the phase selector state to be maintained until the element resets. The one exception to this is when the phase selector decision changes while an element is operated. In this case, the selected elements are reset and the two cycle period re-starts with the new selection.

Note	*Any existing trip decision is not reset under this condition. After the first cycle following a selection, the phase selector is only permitted to change to a selection involving additional phases.*

On double phase to ground faults, only the appropriate phase-phase elements are enabled. The indication of the involvement of ground is by operation of a biased neutral current level detector.

1.4.1 Theory of Operation

Selection of the faulted phase(s) is performed by comparing the magnitudes of the three phase-to-phase superimposed currents. A single phase-to-ground fault produces the same superimposed current on two of these signals and zero on the third. A phase-to-phase or double phase-to-ground fault produces one signal which is larger than the other two. A three phase fault produces three superimposed currents which are the same size. Reference is made to Figure 3 to show how the change in current can be used to select the faulted phases for a CN fault.

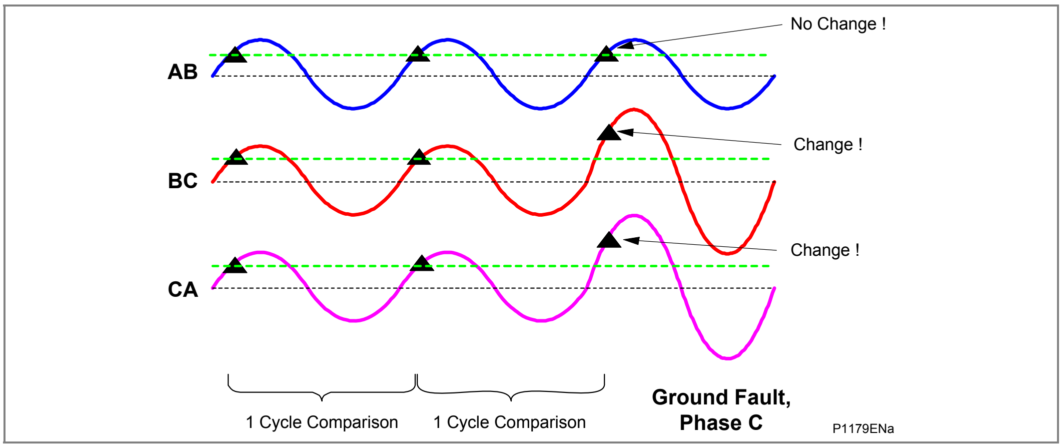


Figure 3 - Phase to phase currents showing change for CN fault

A superimposed current is deemed to be large enough to be included in the selection if it is greater than 80% of the largest superimposed current.

A controlled decay of the superimposed threshold ensures that the phase selector resets correctly on fault clearance.

Phase selection can only be made when any superimposed current exceeds 4% of nominal current (In) as a default value.

Under normal power system conditions, the superimposed currents are made by subtracting the phase-phase current sample taken 96 samples (2 cycles) earlier from the present sample.

When a fault is detected, resulting in a phase selection being made, the "**previous**" memorized sample used in the superimposed current calculation is taken from a re-cycled buffer of "**previous**" samples. This ensures that, if the fault develops to include other phases, the original selection is not lost. The re-cycling of the pre-fault buffers is continued until the phase selector resets, either because the fault is cleared or when the 5 cycle period has expired and no element has operated.

Under conditions on load with high levels of sub-synchronous frequencies, it is necessary to increase the ∆I phase selector threshold from its default (4% In) to prevent sporadic operation. This is automatically performed by the relay, which will self-adjust the threshold to prevent operation upon the noise signals, whilst still maintaining a high sensitivity to faults.

In order to facilitate testing of the Distance elements using test sets which do not provide a dynamic model to generate true fault delta conditions, a Static Test Mode setting is provided. This setting is found in the COMMISSIONING TESTS menu column. When set, this disables phase selector control and forces the relay to use a conventional (non-delta) directional line.

1.5 Mho Element Polarization and Expansion

To ensure coverage for close-up faults, distance protection always includes a proportion of voltage memory. Thus, when each zone characteristic is determined, the phase comparator used in the zone decision will use a mix of vectors "**V**" (the directly measured phase/line voltage), "**IZ**" (a voltage constructed from the fault current and zone impedance reach setting) and "**Vpol**" (a polarizing voltage). The MiCOM P443/P446 allows the user to specify the composition of Vpol, deciding on how to mix the proportion of two voltage selections:

The amount of directly measured ("**self**") polarizing in the mix;

The amount of clean memory stored from before the fault inception.

One of the additional benefits in adding memory into the polarizing mix is that mho characteristics will offer dynamic expansion in the event of a forward fault. This phenomenon is shown in Figure 4 for the default setting Vpol=1, where a Zone 1 characteristic with reach Z will grow to cover 50% of Zs to cover more fault arc resistance.

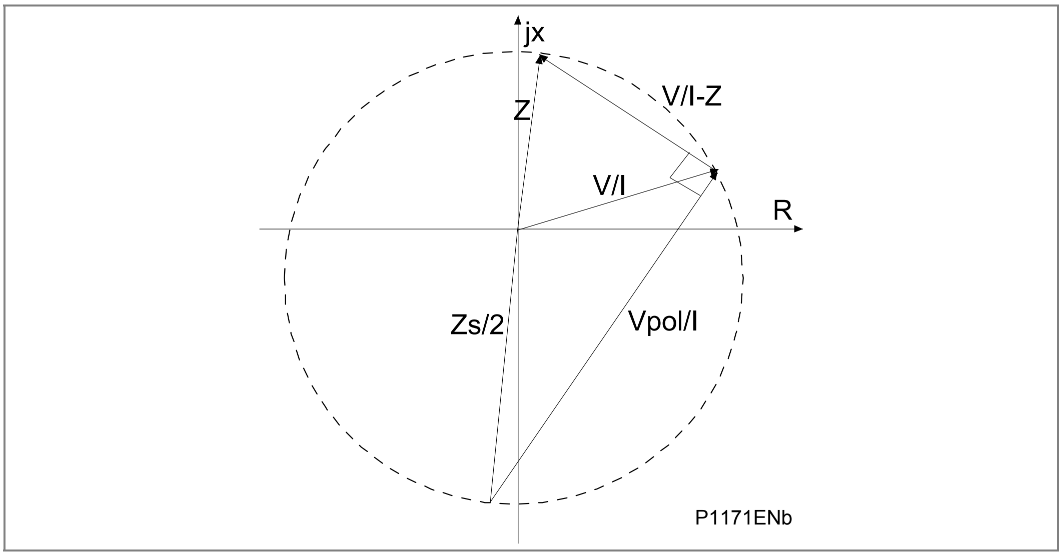


Figure 4 - Expansion of zone 1 for the default polarizing setting Vpol=1

Key: Zs = Source impedance behind the relay location

The MiCOM P443/P446 does not allow the polarizing to be selected as entirely self polarized, or entirely memory polarized. Vpol always contains the directly measured self-polarized voltage, onto which a percentage of the pre-fault memory voltage can be added. The percentage memory addition is settable within the range 0.2 (20%) to 5 (500%).

Setting 20% means that the majority of the polarizing will be self-polarizing, with minimal mho circle expansion, and just enough memory to counteract any CVT transients. Setting 500% means that in the overall polarizing mix the ratio would be 1 part self polarizing to 5 parts memory. Such a high memory content would offer large dynamic expansion, covering 83% of the source impedance (Zs) behind the relay.

- Mho expansion = [(Polarizing Setting)/(Setting + 1)] . Zs

This characteristic is used for Zones 1, P (optionally reversed), 2, 4 and Zone 3 if the offset is disabled.

The characteristic is generated by a phase comparison between V/I-Z and the polarizing signal Vpol

Where:

V is the fault voltage

Vpol is a user selected mix of the fault voltage and pre-fault memory

I Is the fault current

Z Is the zone reach setting (including residual compensation for ground fault elements)

Zs Is the source impedance (included in 0 to show the position of the Vpol phasor)

The polarizing signal Vpol is a combination of the fault voltage and the stored vector taken from 2 cycles before the fault, which is a representation of the volts at the source.

Vpol = IZs + V

or

Vpol/I = Zs + V/I

Operation occurs when the angle between the signals is greater than 90°, which is for faults inside the circle.

The validity of the voltage memory in MiCOM P443/P446 extends to 16 cycles after loss of the VT input voltage. If no memory is available, the polarizing signal is substituted by cross polarizing from the unfaulted phase(s). For example if Vamem is unavailable, the voltages measured on phases B and C now are used, phase-shifted as necessary.

To produce the reversed zones (Zone 4 and optionally Zone P) the impedance Z is automatically set to a negative value.

1.5.1 Switch On To Fault Action for Zone 1

Operation of the distance elements is generally prevented if the polarizing signal magnitude is insufficient (less than 1V). The exception is for Zone 1, which following breaker closure is allowed to operate with a small (10%) reverse offset. This is to ensure operation when closing on to a close-up three phase fault (Scenario: earthing/ground clamps inadvertently left in position).

In addition Z4 reverse operation is held if it operates in memory.

Other zones may have their zone time delays bypassed for SOTF/TOR, as detailed in the application notes.

1.5.2 Offset Mho

If the Zone 3 offset is enabled then it uses no memory polarizing and has a fixed reverse offset from the origin of a distance polar diagram. Characteristic angle and residual compensation as per the forward settings.

1.6 Quadrilateral Elements

The quadrilateral elements are made from combinations of reactance lines, directional lines and load blinders.

A counter, similar to that used for the mho element, is incremented when all the relevant phase comparisons indicate operation. A fast up-count of 6 is issued when the fault is within 80% of the reach of the zone, and well within the resistive reach boundary. Elsewhere, the increment is always 1 but a fast decrement (6) is used when the faulted phase current is less than half the minimum operating current setting. Thus, an area of fast operation for faults near the characteristic angle is always available, whether mho or quadrilateral characteristics are applied.

1.6.1 Directional Quadrilateral

This characteristic is used for Zones 1, P (optionally reversed), 2 and 4 (reversed).

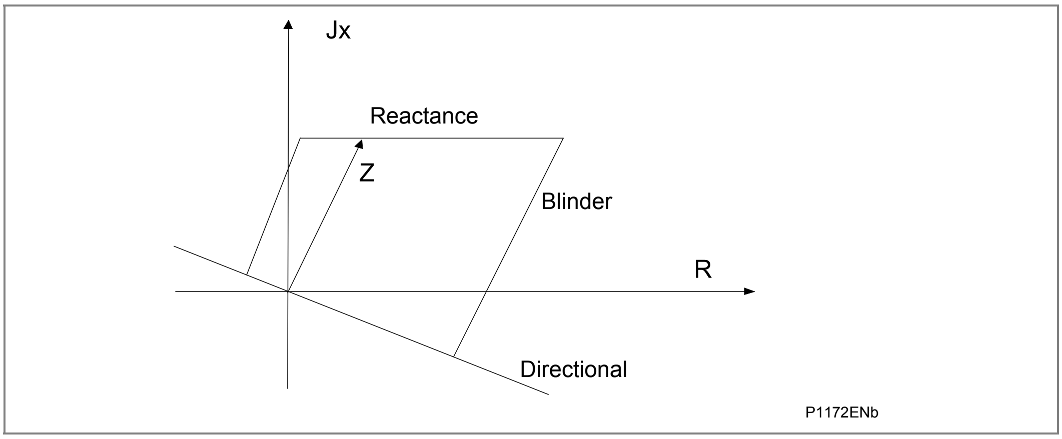


Figure 5 - Quadrilateral characteristics (directional line shown simplified)

It is formed from two parallel reactance lines, two parallel resistive reach blinders and controlled by the delta or conventional directional line. The bottom reactance line (not shown on Figure 5) and the left hand reach blinder are automatically set to 25% of the reactance reach and the right hand blinder, respectively. The reactance line is arranged to operate for faults below the line, the blinders for faults within the resistive reach limits, and the delta directional line for forward faults. The counter increments when all of these conditions are satisfied.

1.6.2 Offset Quadrilateral

This characteristic is used for Zone 3 when the offset is enabled.

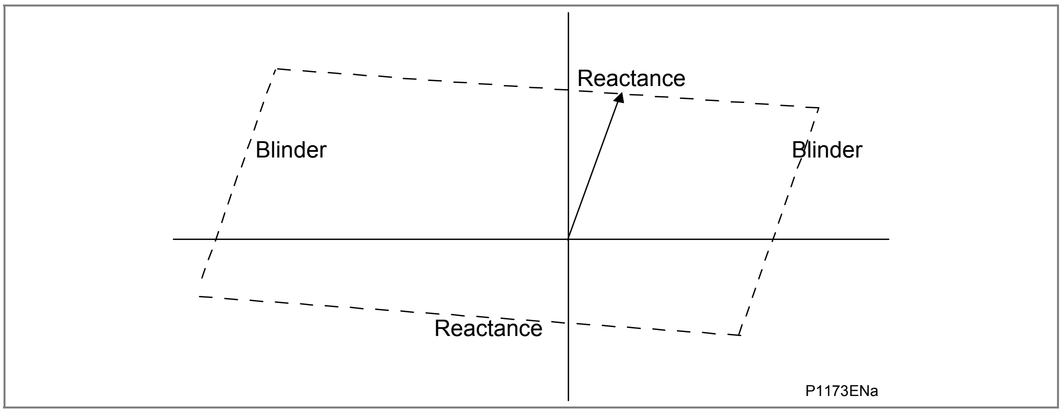


Figure 6 - Offset quadrilateral for zone 3

It is formed from two reactance lines and two resistive reach blinders. The upper reactance line is arranged to operate for faults below it and the lower for fault above it. The right hand blinder is arranged to operate for faults to its left and the left hand blinder for faults to its right. The counter increments when all these conditions are satisfied.

It should be noted that when Zone 3 is set offset in simple setting mode, the left hand blinder and lower reactance line equal the offset percentage setting of the line impedance and fault resistance respectively. In the advanced setting mode, both lines can be set independently.

1.6.3 Reactance Line - Top Line of Quadrilateral

The MiCOM P443/P446 provides a flexible user settable top reactance line tilting mode:

1. Dynamic (self adaptive) tilt angle - applicable to ground distance only
2. Fixed tilt angle - applicable to phase distance and ground distance if Dynamic tilting is disabled

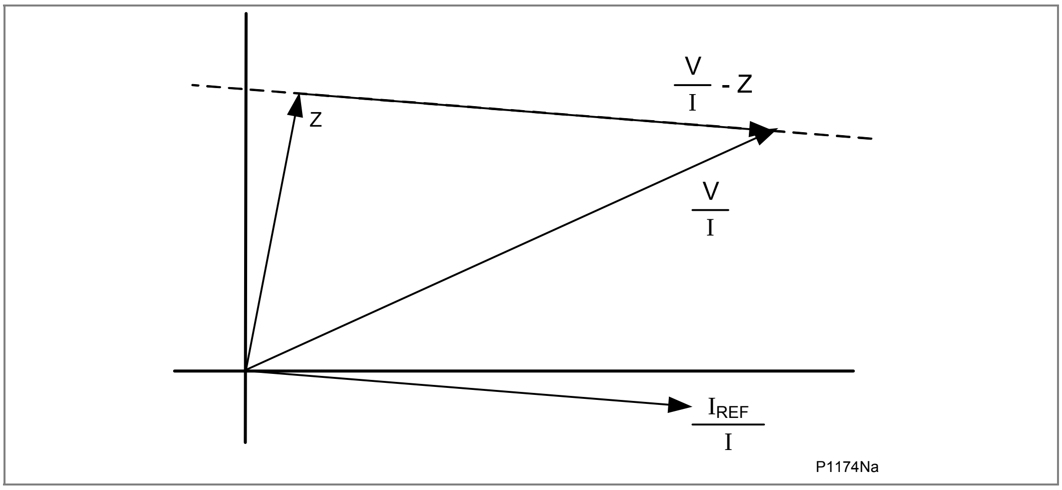


Figure 7 - Reactance line - top line of quadrilateral

A reactance line is formed by the phase comparison between an operating signal V/I - Z, which is the same as that used for the equivalent mho element, and a polarizing signal Iref/I.

Where:

V is the fault voltage

I is the fault current (always presented at zero degree)

Z is the zone reach setting, including residual compensation

Iref is the negative sequence current for dynamic tilting or phase current for the fixed angle tilting that includes the initial tilt angle setting (set to -3° as default).

1.6.3.1 Dynamic Tilting:

When the Dynamic tilting is selected by a user, the top line of the ground distance quadrilateral characteristic will start tilting from the user settable angle (default angle is -3°) and tilt further for the angle difference between the fault current and the negative sequence current so that an overall tilt angle with the reference to fault (phase) current '**I**' will be:

Tilt angle = $\angle$Iref/**I** = setting + $\angle$(Iph−I2)

Operation occurs when the operating signal lags the polarizing signal.

The default starting (initial) tilt angle of -3° is introduced to reduce the possibility of overreach caused by any small differences between the negative sequence source impedances, and general CT/VT angle tolerances.

Negative sequence current is used for ground fault Iref since it provides a better estimate of the current in the fault than either the faulted phase current or zero sequence current. As a result the reactance line follows the fault resistance impedance and tilts up or down (depending on the load direction) starting from the set initial tilt angle to avoid underreach or overreach.

The following additional constraints also exist to ensure that the top line does not tilt too far:

- The Zone 1 reactance (top) line can only stay at set initial tilt angle (-3° default) compared to the resistive axis, or can tilt down by $\angle$(Iph-I2) . The top line may never tilt up from set tilting angle, to ensure that Zone 1 does not overreach. This maintains grading/selectivity with downstream protection.
- The Zone 2 reactance (top) line can only ever stay at set tilt angle (-3° default) compared to the resistive axis, or can tilt up by $\angle$(Iph-I2). The top line may never tilt down, to ensure that Zone 2 does not underreach. This is particularly important when Zone 2 is used to key channel-aided distance schemes.
- The maximum permissible tilt is +/- 45° either side of the set initial tilt angle (-3° default)

When one circuit breaker pole is open, during a single pole re-close sequence, the polarizing signal is replaced by the fault current with a -7° phase shift, allowing the protection of the remaining phases, even though the negative sequence current is not available. The additional phase shift is provided to reduce the possibility of overreach caused by the faulted phase as the reference.

1.6.3.2 Predetermined (Fixed Angle) Tilting:

For the phase quadrilateral characteristics and ground quad characteristics in case when dynamic tilting is disabled, the fix angle setting settable by a user applies. Each zone has an independent tilt angle setting. The total tilting angle with the reference to fault current '**I**' is equal to the set angle:

Tilt angle = $\angle$Iref/**I** = setting

Note	*A minus angle is used to set a downwards tilt gradient, and a positive angle to tilt upwards.*

Operation occurs when the operating signal lags the polarizing signal. The setting range is +/- 30°.

1.6.4 Right Hand Resistive Reach Line

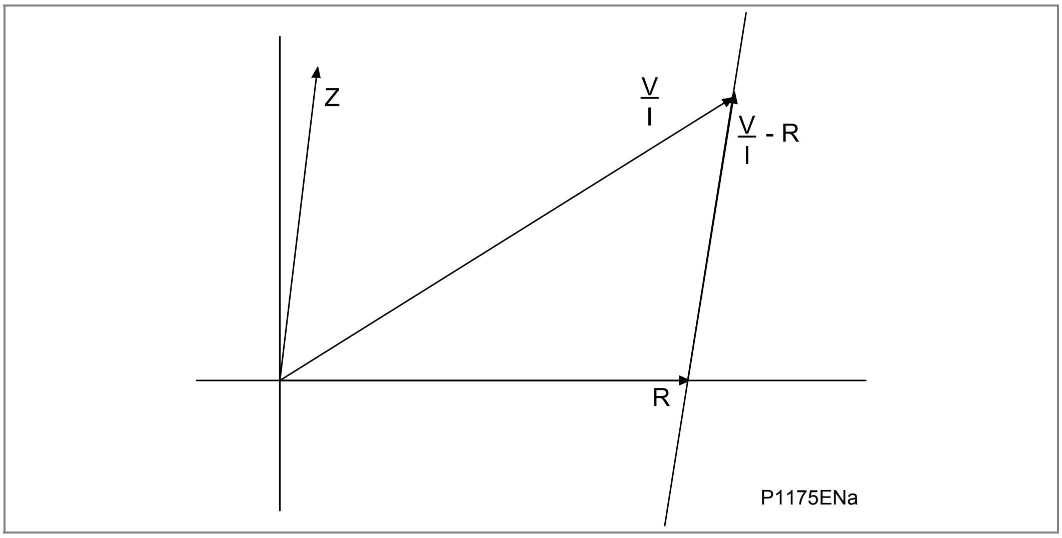


Figure 8 - Resistive reach line (load blinder)

A load blinder is formed by the phase comparison between an operating signal V/I - R and a polarizing signal Z

Where:

V Is the fault voltage

I Is the fault current

R Is the resistive reach of the blinder

Z zone reach setting (including neutral compensation for ground distance)

Operation occurs when the operating signal leads the polarizing signal.

1.7 Quadrilateral Phase Resistive Reaches

The resistive reach setting is used to select the resistive intercept of the quadrilaterals – the right-hand side of the zone.

Note	*The RPh setting applied defines the fault arc resistance that can be detected for a phase-phase fault. For such a fault, half of the fault resistance appears in the positive sequence network, and half in the negative sequence network. Thus, as most injection test sets will plot impedance characteristics in positive sequence terms, the right-hand intercept will be found at half the setting applied (= Rph/2).*

1.8 Quadrilateral Ground Resistive Reaches

The resistive reach setting is used to select the resistive intercept of the quadrilaterals – the right-hand side of the zone.

Note *The RG setting applied defines the fault arc resistance that can be detected for a single phase-ground fault. For such a fault, the fault resistance appears in the out and return total fault loop, in which the line impedance is Z1 x (1 + kZN). Thus, as most injection test sets will plot impedance characteristics in positive sequence terms, the right-hand intercept will be found at less than setting applied (= RG/[1+kZN]).*

1.9 Line Parameters Settings

1.9.1 Phase Rotation

A setting is used to select whether the 3 phase voltage set is rotating in the standard ABC sequence, or whether the rotation is in reverse ACB order. The appropriate selection is required to ensure that all sequence components and faulted phase flagging/targeting is correct.

1.9.2 Tripping Mode - Selection of Single or Three Phase Tripping

This selects whether instantaneous trips are permitted as Single pole, or will always be 3 pole. Protection elements considered as “**instantaneous**” are those normally set to trip with no intentional time delay, i.e.: directional earth/ground DEF aided scheme and if fitted, Zone 1 distance and distance channel aided scheme. The selection “**1 and 3 pole**” allows single pole tripping for single phase to ground faults. The selection “**3 pole**” converts all trip outputs to close Trip A, Trip B and Trip C contacts simultaneously, for three pole tripping applications.

In the case of the P446, the tripping mode can be set independently for the two circuit breakers controlled.

Logic is provided to convert any double phase fault, or any evolving fault during a single pole auto-reclose cycle into a three phase trip. Two phase tripping is never permitted. This functionality is shown in Figure 9 for P443 and in Figure AR 123 (logic diagram supplement) for P446 models.

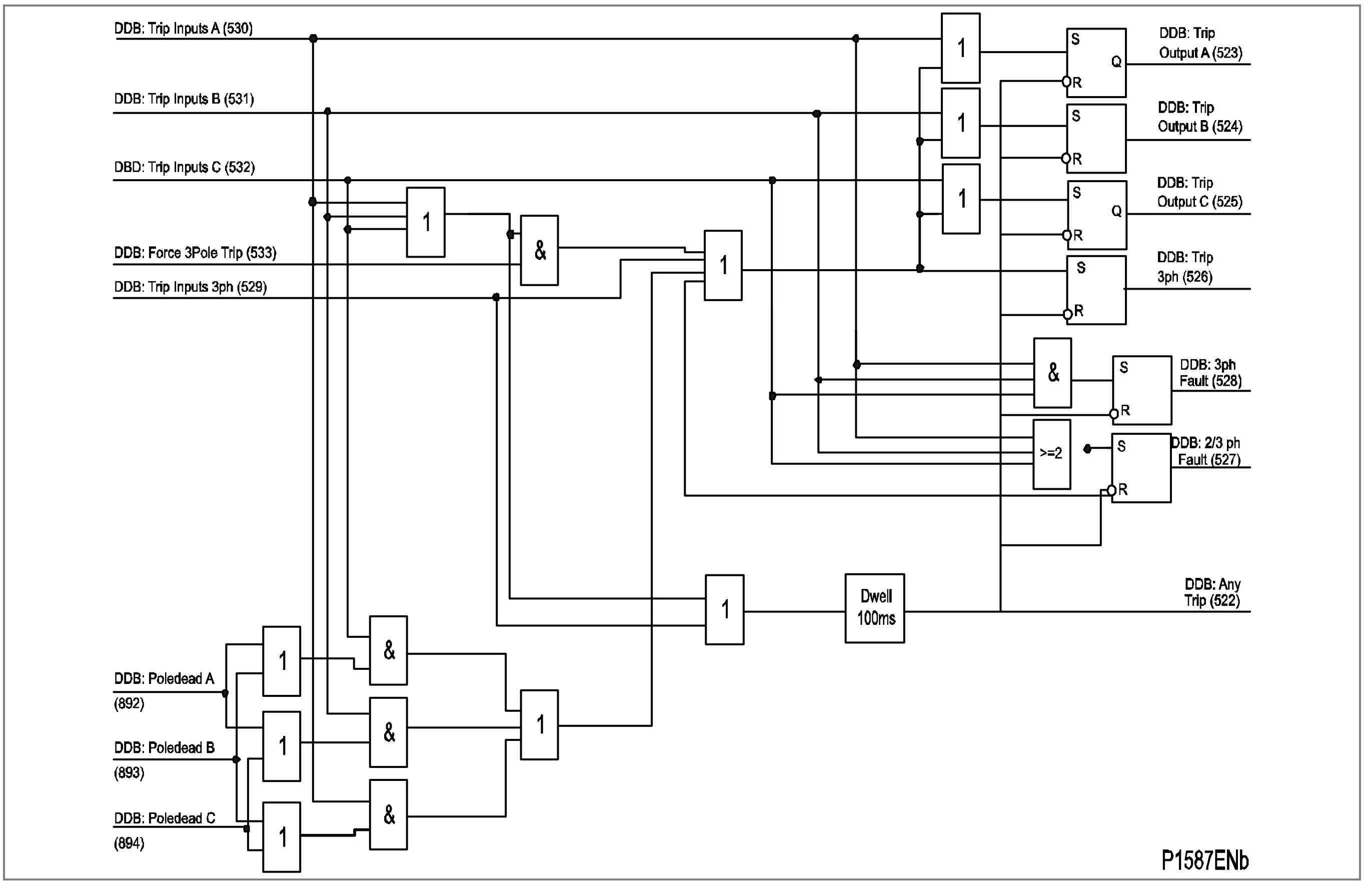

DDB: Trip Inputs A (530)
DDB: Trip Inputs B (531)
DBD: Trip Inputs C (532)
DDB: Force 3Pole Trip (533)
DDB: Trip Inputs 3ph (529)
DDB: Poledead A (892)
DDB: Poledead B (893)
DDB: Poledead C (894)
1
&
>=2
S
R
Q
Dwell 100ms
DDB: Trip Output A (523)
DDB: Trip Output B (524)
DDB: Trip Output C (525)
DDB: Trip 3ph (526)
DDB: 3ph Fault (528)
DDB: 2/3 ph Fault (527)
DDB: Any Trip (522)
P1587ENb

Figure 9 - Trip conversion scheme logic

1.9.3 Pole Dead Logic

Pole dead logic is used by the relay to determine when the circuit breaker poles are open (“**pole dead**”). This indication may be forced, by means of status indication from CB auxiliary contacts (52a or 52b), or internally determined by the relay. When no auxiliary contacts are available, the relay uses lack of phase current (Setting: CB FAIL & I</UNDER CURRENT/I< Current Set), and an undervoltage level detector (pick up fixed at 38.1V - drop off fixed at 43.8V to declare a “**pole dead**”.

Note	If the VT is connected at the busbar side, auxiliary contacts (52a or 52b) must be connected to the relay for a correct pole dead indication. The logic diagrams, Figure 10 and Figure 11 show the details:

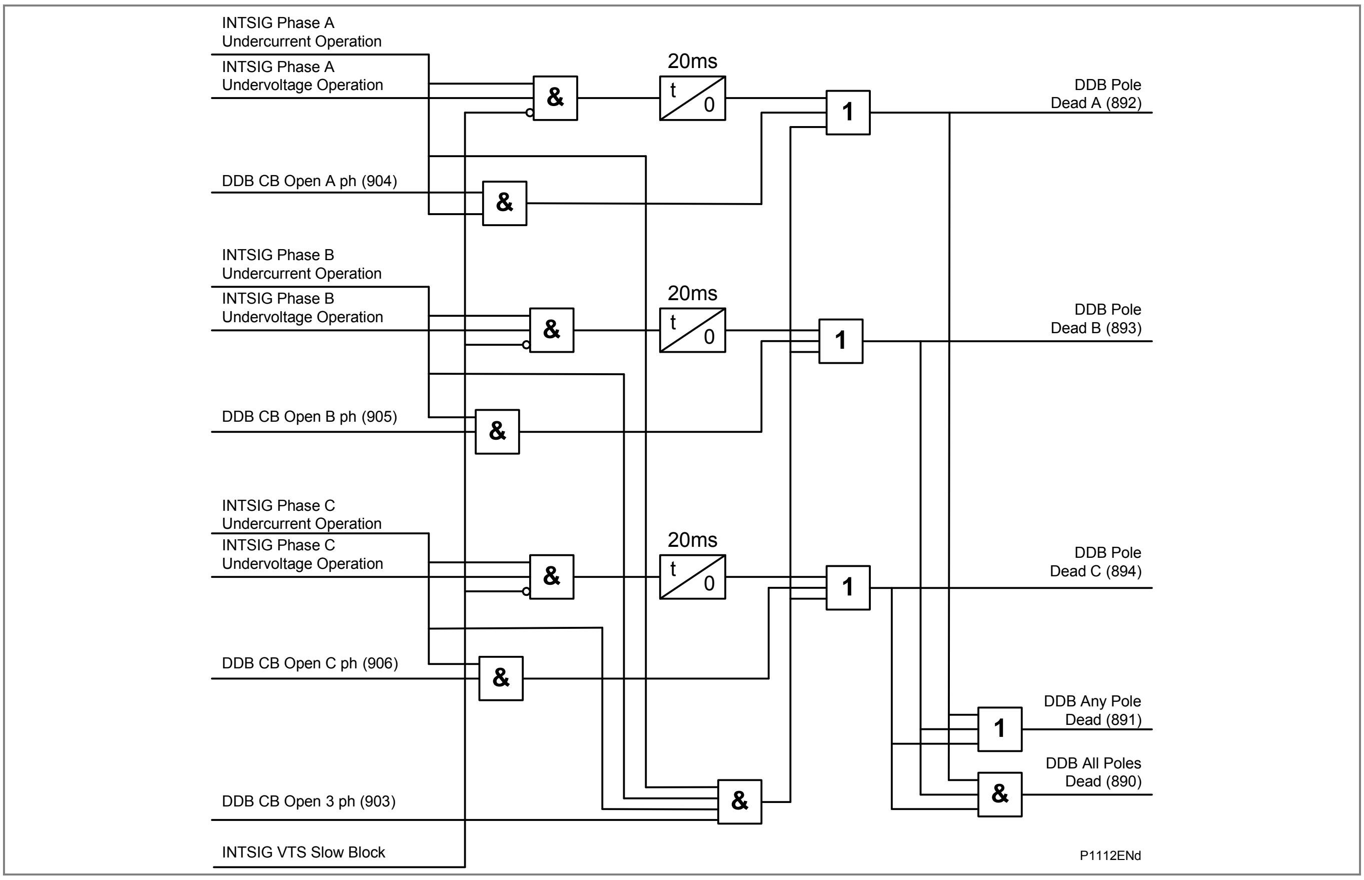

INTSIG Phase A Undercurrent Operation
INTSIG Phase A Undervoltage Operation
DDB CB Open A ph (904)
INTSIG Phase B Undercurrent Operation
INTSIG Phase B Undervoltage Operation
DDB CB Open B ph (905)
INTSIG Phase C Undercurrent Operation
INTSIG Phase C Undervoltage Operation
DDB CB Open C ph (906)
DDB CB Open 3 ph (903)
INTSIG VTS Slow Block
&
20ms
t
0
1
DDB Pole Dead A (892)
DDB Pole Dead B (893)
DDB Pole Dead C (894)
DDB Any Pole Dead (891)
DDB All Poles Dead (890)
P1112ENd

Figure 10 - Pole dead logic for MiCOM P443

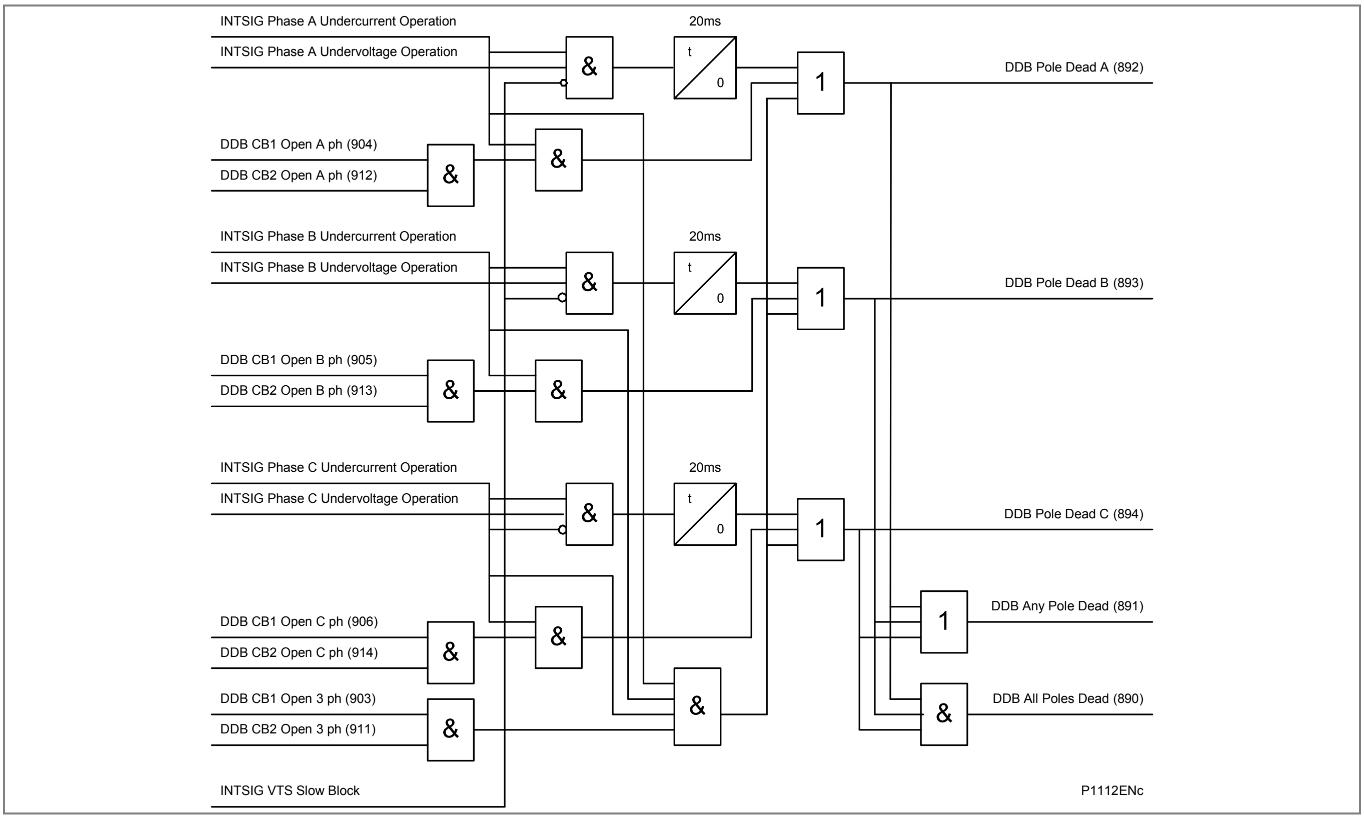

INTSIG Phase A Undercurrent Operation
INTSIG Phase A Undervoltage Operation
DDB CB1 Open A ph (904)
DDB CB2 Open A ph (912)
INTSIG Phase B Undercurrent Operation
INTSIG Phase B Undervoltage Operation
DDB CB1 Open B ph (905)
DDB CB2 Open B ph (913)
INTSIG Phase C Undercurrent Operation
INTSIG Phase C Undervoltage Operation
DDB CB1 Open C ph (906)
DDB CB2 Open C ph (914)
DDB CB1 Open 3 ph (903)
DDB CB2 Open 3 ph (911)
INTSIG VTS Slow Block
&
20ms
t
0
1
DDB Pole Dead A (892)
DDB Pole Dead B (893)
DDB Pole Dead C (894)
DDB Any Pole Dead (891)
DDB All Poles Dead (890)
P1112ENc

Figure 11 - Pole dead logic for MiCOM P446

1.9.4 Residual Compensation for Earth/Ground Faults

For earth faults, residual current (derived as the vector sum of phase current inputs (Ia + Ib + Ic) is assumed to flow in the residual path of the earth loop circuit. Thus, the earth loop reach of any zone must generally be extended by a multiplication factor of (1 + kZN) compared to the positive sequence reach for the corresponding phase fault element.

Caution **The kZN Angle is different than previous LFZP, SHNB, and LFZR relays: When importing settings from these older products, subtract angle ∠ Z1.**

1.9.5 Mutual Compensation for Parallel Lines

When applied to parallel circuits mutual flux coupling can alter the impedance seen by the fault locator, and distance zones. The effect on the ground distance elements and on the fault locator of the zero sequence mutual coupling can be eliminated by using the mutual compensation feature provided. This requires that the residual current on the parallel line is measured, as shown in the connection diagram. It is extremely important that the polarity of connection for the mutual CT input is correct.

The major disadvantage of standard mutual compensation is that faults on a parallel line can cause mal-operation of the healthy line protection. The MiCOM P443/P446 uses fast dynamic control of the mutual compensation, which prevents such mal-operations of the healthy line protection, while providing correct mutual compensation for faults inside the protected section. The dynamic control is achieved by effectively eliminating the mutual compensation above a set level of parallel line residual current (I MUTUAL) compared to the protected line residual current (IN).

- If the ratio: I MUTUAL/IN is less than the ‘***Mutual Cutoff***’ setting, then full mutual compensation is applied to all distance zones, and the fault locator.
- If the ratio: I MUTUAL/IN is greater than the ‘***Mutual Cutoff***’ setting, then no mutual compensation is applied.

1.10 Advanced Distance Elements Zone Settings

For most applications the user will configure the relay in "**Simple**" setting mode, whereby all zone reaches are based on the protected line impedance, scaled by a reach percentage. In such a case there is then no need to set the individual zone ohmic reaches and compensation factors, because the automatic calculation will already have determined these settings. Thus with Simple settings, the menu column "**GROUP x DISTANCE ELEMENTS**" will merely be a list of what settings have been automatically calculated and applied. This list is useful as a reference when commissioning and periodic injection testing.

Using the "**Advanced**" setting mode, the user has decided to set all the zones him/herself, and must complete all the reach and residual/mutual compensation settings on a per zone basis.

Note *Distance zones are directionalized (where applicable) by a delta directional decision. The characteristic angle for this decision is set along with the Delta Directional configuration, in the "**GROUP x DIRECTIONAL FN**" menu column. The default setting is 60°.*

1.10.1 Phase Fault Zone Settings

It can be noted that each zone has two additional settings that are not accessible in the Simple set mode. These settings are:

- A tilt angle on the top line of any quadrilateral set for phase faults;
- A minimum current sensitivity setting.

By factory defaults, the Top Line of quadrilateral characteristics is not fixed as a horizontal reactance line. To account for phase angle tolerances in the line CT, VT and relay itself, the line is tilted downwards, at a "**droop**" of -3°. This tilt down helps to prevent zone 1 overreach.

In "**Advanced**" setting mode, the Top line tilt is settable.

The current *Sensitivity* setting for each zone is used to set the minimum current that must be flowing in each of the faulted phases before a trip can occur. If for example a phase A-B line fault is present, the relay must measure both currents Ia and Ib above the minimum set sensitivity. The default setting is 7.5% In for Zones 1 and 2, 5% In for other zones, ensuring that distance element operation is not constrained, right through to an SIR ratio of 60.

1.10.2 Ground Fault Zone Settings

It should be noted that the Ground reach settings (Reach and Angle) are set according to the **positive sequence line impedance,** and so will generally be identical to the Phase reach settings.

The Top Line of ground quadrilateral characteristics is not fixed as a horizontal reactance line. To account for phase angle tolerances in the line CT, VT and relay itself, the line is tilted downwards, at a "**droop**" of -3°. This tilt down helps to prevent zone 1 overreach. However, to further improve performance this line incorporates an additional dynamic tilt, which will change according to the phase angle between the faulted phase current and the negative sequence current:

- Zone 1 is allowed to tilt down to avoid overreaching for pre-fault power export;
- Zones 2 and 3 are allowed to tilt up to avoid underreaching for pre-fault power import.

As the tilt is dynamic, this is why ground fault elements do not have a setting for the angle.

The current *Sensitivity* setting for each zone is used to set the minimum current that must be flowing in the faulted phase and the neutral before a trip can occur. If for example an A-ground fault is present the relay must measure both currents Ia and Iresidual above the minimum set sensitivity.

The default setting is 7.5% In for Zones 1 and 2, 5% In for other zones, ensuring that distance element operation is not constrained, right through to an SIR ratio of 60.

1.10.3 Distance Zone Sensitivities

It should be noted that when the "**Simple**" setting mode is selected, the minimum current sensitivity still applies, but the value is automatically calculated and applied based on the data entered into the simple settings fields. The criteria used to calculate the setting value is required to satisfy a minimum value of current flowing in the faulted loop and a requirement on the Zone reach point voltage. For Zones 3, P, and 4, the requirements are that the minimum current must be greater than 5% of rated current, and that the minimum voltage at the Zone reach point is 0.25V. The current equating to the reach point criteria can be expressed as 0.25/Zone reach, and the sensitivity can be expressed as:

Sensitivity (Z3, ZP, Z4) = max (5%In, (0.25/Zone reach))

For Zones 1 and 2, the sensitivity is further qualified to ensure that they are set less sensitive that the reverse Zone 4. This is designed to ensure stability of the relay where applied with either an overreaching, or a blocking scheme. For Zones 1 and 2, the same criteria as for Zones 3, P, and 4 are applied, but in addition a minimum sensitivity criterion dependent upon the Zone 4 sensitivity is applied: the sensitivity must also exceed 1.5 x Zone 4 sensitivity. The sensitivity can be expressed as:

Sensitivity (Z1, Z2) = max (5%In, (0.25/Zone reach), (1.5 x Zone 4 sensitivity))

Or

Sensitivity (Z1, Z2) = max (5%In, (0.25/Zone reach), (1.5 x (0.25/Zone 4 reach)))

It should be noted that the dependency on the Zone 4 element always applies, even if Zone 4 is disabled.

It should further be noted that the default reach setting for Zones 1, 2 and 4 are 80%, 120%, and 150% respectively and for these settings, the "**Zone dependent**" terms can be reduced to:

0.25/Zone 1 reach = 0.25/(0.8 x line impedance)

0.25/Zone 2 reach = 0.25/(1.2 x line impedance)

1.5 x (0.25/Zone 4 reach) = 0.25/line impedance

In such cases, for Zone 1, the dominant Zone reach term will be that of Zone 1 and the equation can be reduced to:

Sensitivity (Z1) = max (5%In, (0.25/(0.8 x line impedance)))

It can be shown that for lines with an impedance less than 6.25 Ω the Zone 1 reach term will dominate and the sensitivity will be greater than 5% In. Above this line impedance the sensitivity will be 5% In.

Similarly, for Zone 2, the dominant Zone reach term will be that of Zone 4 and the equation can be reduced to:

Sensitivity (Z2) = max (5%In, (0.25/line impedance))

It can be seen that for lines with an impedance less than 5 Ω the Zone reach term will dominate and the sensitivity will be greater than 5% In. Above this line impedance the sensitivity will be 5% In.

In “**Advanced**” mode the same restrictions as minimum sensitivity should be applied to ensure distance element accuracy.

1.11 Conventional Voltage Transformer and Capacitor VT Applications

The MiCOM P443/P446 achieves fast trip times due an optimized counting strategy. For faults on angle and up to 80% of the set reach of the zone, a counter increments quickly to reach the level at which a trip is issued. Near the characteristic boundary, the count increments slower to avoid transient overreach, and to ensure boundary accuracy. This strategy is entirely sufficient where conventional wound voltage transformers are used. Thus, where capacitor-coupled voltage transformers (CVT) are not employed, the setting “**CVT Filters**” can be set to Disabled.

Where capacitor-coupled voltage transformers are employed, then for a close-up fault the transient component can be very large in relation to the fundamental component of fault voltage. The relay has setting options available to allow additional filtering to be switched-in when required, and the filter options to use depend on the likely severity of the CVT transient. The two filtering methods are explained below.

1.11.1 CVTs with Passive Suppression of Ferroresonance

Passive suppression employs an anti-resonance design, and the resulting transient/distortion is fairly small. Sometimes such suppression is classed as a “**type 2**” CVT. In passive CVT applications, the affect on characteristic accuracy is generally negligible for source to line impedance ratios of less than 30 (SIR < 30). However, at high SIRs it is advisable to use the slower count strategy. This is achieved by setting “***CVT Filters***” to “**Passive**”.

It is important to note that by enabling this filter, the relay will not be slowed unless the SIR is above that set. If the line terminal has an SIR below the setting, the relay can still trip subcycle. It is only if the SIR is estimated higher than the setting that the instantaneous operating time will be increased by about a quarter of a power frequency cycle. The relay estimates the SIR as the ratio of nominal rated voltage Vn to the size of the comparator vector IZ (in volts):

SIR = Vn/IZ

Where:

Vn = Nominal phase to neutral voltage

I = Fault current

Z = Reach setting for the zone concerned

Thus for slower counting “**I**” would need to be low, as restricted by a relatively weak infeed, and “**Z**” would need to be small as per a short line.

1.11.2 CVTs with Active Suppression of Ferroresonance

Active suppression employs a tuned L-C circuit within the CVT. The damping of transients is not as efficient as for the passive designs, and such suppression is often termed as being a “**type 1**” CVT. In active CVT applications, to ensure reach point accuracy the setting “**CVT *Filters***” is set to “**Active**”. The relay then varies the count strategy according to the calculated SIR (= Vn / IZ). Subcycle tripping is maintained for lower SIRs, up to a ratio of 2, with the instantaneous operating time increasing by about a quarter of a power frequency cycle at higher SIRs.

Transients caused by voltage dips, however severe, will not have an impact on the relay's directional measurement as the MiCOM P443/P446 uses voltage memory.

1.12 Load Blinding (Load Avoidance)

Load blinders are provided for both phase and ground fault distance elements, to prevent mal-operation (mal-tripping) for heavy load flow. The purpose is to configure a blinder envelope which surrounds the expected worst case load limits, and to block tripping for any impedance measured within the blinded region. Only a fault impedance which is outside of the load area will be allowed to cause a trip. The blinder characteristics are shown in Figure 12.

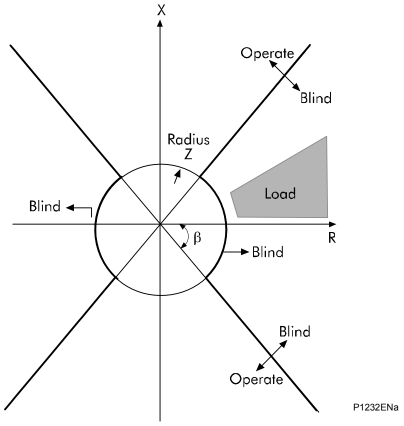


Figure 12 - Load blinder characteristics

In Figure 12:

- Z denotes the Load/B Impedance setting. This sets the radius of the underimpedance circle.
- β denotes the Load/B Angle setting. This sets the angle of the two blinder boundary lines - the gradient of the rise or fall with respect to the resistive axis.

The MiCOM P443/P446 has a facility to allow the load blinder to be bypassed any time the measured voltage for the phase in question falls below an undervoltage V< setting. Under such circumstances, the low voltage could not be explained by normal voltage excursion tolerances on-load. A fault is definitely present on the phase in question, and it is acceptable to override the blinder action and allow the distance zones to trip according to the entire zone shape. The benefit is that the resistive coverage for faults near to the relay location can be higher.

1.13 Distance Elements Basic Scheme Setting

Configuration of which zones will trip, and the zone time delays is set in the menu column "**GROUP x SCHEME LOGIC**" (where "**x**" is the setting group). Phase and ground elements may have different time delays if required. Operation of distance zones according to their set time delays is termed the "**Basic Scheme**", and is shown in Figure 13. The basic scheme always runs, regardless of any channel-aided acceleration schemes which may be enabled (see later).

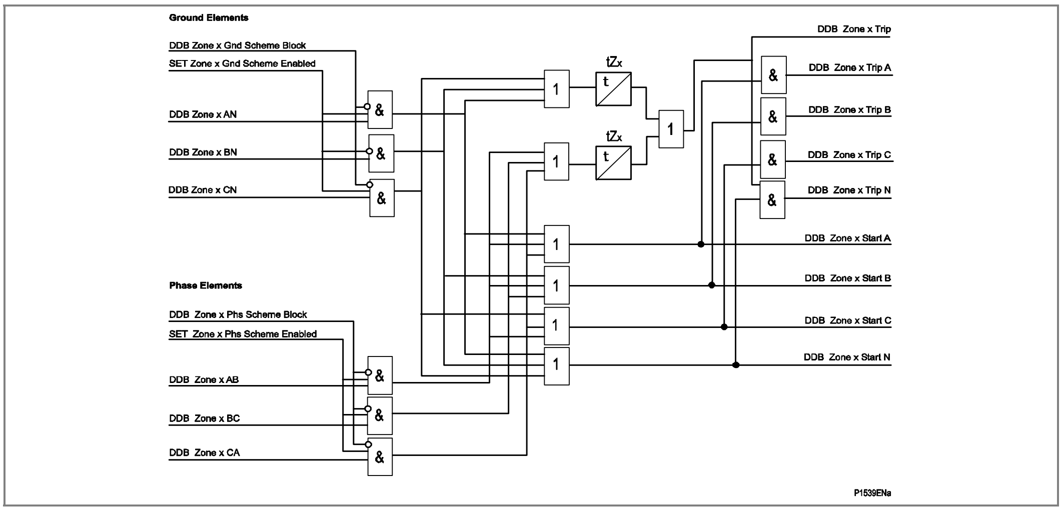

Ground Elements
DDB Zone x Gnd Scheme Block
SET Zone x Gnd Scheme Enabled
DDB Zone x AN
DDB Zone x BN
DDB Zone x CN
Phase Elements
DDB Zone x Phs Scheme Block
SET Zone x Phs Scheme Enabled
DDB Zone x AB
DDB Zone x BC
DDB Zone x CA
&
1
tZx
t
DDB Zone x Trip
DDB Zone x Trip A
DDB Zone x Trip B
DDB Zone x Trip C
DDB Zone x Trip N
DDB Zone x Start A
DDB Zone x Start B
DDB Zone x Start C
DDB Zone x Start N
P1539ENa

Figure 13 - Basic scheme delayed trip

Signal	Zone 1	Zone 2	Zone 3	Zone P	Zone 4
Zone x Ground Block	384	386	388	390	392
Zone x Phase Block	385	387	389	391	393
Zone x AN	960	966	972	978	984
Zone x BN	961	967	973	979	985
Zone x CN	962	968	974	980	986
Zone x AB	963	969	975	981	987
Zone x BC	964	970	976	982	988
Zone x CA	965	971	977	983	989
Zone x Trip	608	613	618	623	628
Zone x Trip A	609	614	619	624	629
Zone x Trip B	610	615	620	625	630
Zone x Trip C	611	616	621	626	631
Zone x Trip N	612	617	622	627	632
Zone x Start A	741	745	749	753	757
Zone x Start B	742	746	750	754	758
Zone x Start C	743	747	751	755	759
Zone x Start N	744	748	752	756	760

Note *The numbers in the table represent the DDB signals available in the PSL.*

Table 1 - Signals, Zones and DDB Numbers

1.14 Power Swing Detection, Alarming and Blocking

1.14.1 Detection of Power Swings

A power swing may cause the impedance presented to a distance relay to move away from the normal load area and into one or more of its tripping characteristics. In the case of a stable power swing it is important that the relay should not trip. The relay should also not trip during loss of stability since there may be a utility strategy for controlled system break up during such an event.

The power swing detection in the MiCOM P443/P446 is an advanced technique that uses superimposed current (ΔI) detector similar to the phase selection principle described above. However for the power swing detector the current is always compared to that 2 cycles previous. For a fault condition this power swing detector (PSD) will reset after 2 cycles as no superimposed current is detected.

For a power swing, PSD will measure superimposed current for longer than 2 cycles, and it is the length of time for which the superimposed current persists that is used to distinguish between a fault and a power swing. A power swing is deemed to be in progress if a three phase selection, or a phase to phase selection when one pole is open, produced in this way is retained for more than 3 cycles, as shown in Figure 14. At this point the required distance zones can be blocked, to avoid tripping should the swing impedances cross into a tripping zone.

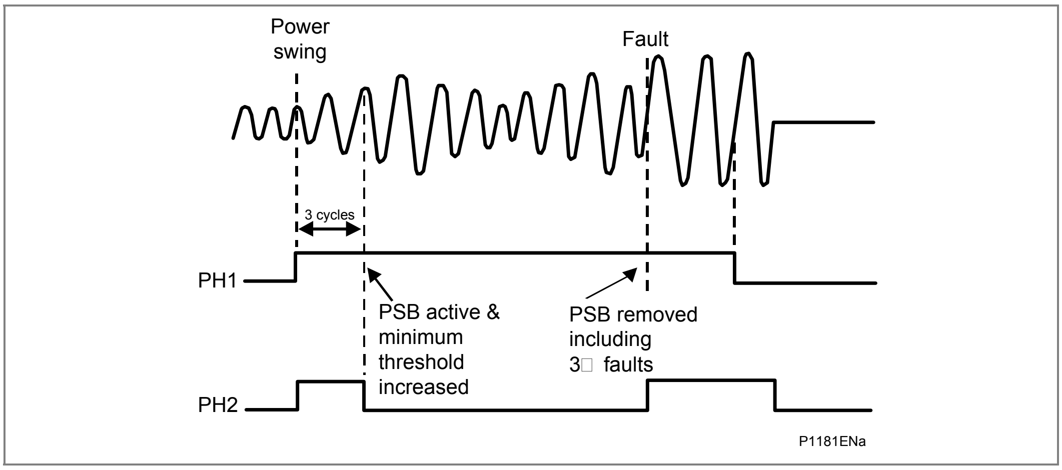

Power swing
Fault
3 cycles
PH1
PSB active & minimum threshold increased
PSB removed including 3□ faults
PH2
P1181ENa

Figure 14 - Power swing detected for 3 cycles continuous ΔI

In order to detect slow power swings, when the superimposed current remains below the minimum threshold (5%In), a complementary method of detection could be used. This method requires zone 5 to be set. For the zone 5 setting, no system study is required, it is only necessary to set the R5 and R5' reach below the minimum possible load impedance, as explained in the Application Section. If the fault impedance remains within a zone 5 for at least 1 cycle without phase selection operation, the slow swing is declared. This complementary method works in parallel to the automatic, setting free technique explained above.

Note	*Zone 5 has a dual purpose: OST protection and slow swing detection. There is no conflict in zone 5 settings, i.e. zone 5 settings for OST protection (if applied) perfectly suit slow swing detection.*

1.14.2 Actions upon Power Swing Detection

Once a power swing is detected the following actions occur:

- Distance elements are blocked on selected zones providing blocking is enabled
- All zones are switched to self polarized mho characteristics for maximum stability during the swing
- A power swing block alarm is issued when the swing impedance enters a distance zone. The condition of entering an impedance zone avoids alarming for low current momentary swings that settle quickly
- When a power swing is in progress, the minimum threshold used by the phase selector is increased to twice the maximum superimposed current prevailing in the swing Therefore, the phase selector resets once a power swing is detected. It can then be used to detect a fault during a power swing.

1.14.3 Detection of a Fault during a Power Swing

A fault is detected during a swing when the phase selector operates, based on its increased threshold. Thus, any operation of the phase selector will cause PSB unblocking, and allow a trip. Example scenarios are:

- A fault causes the delta current measured to increase above twice that stored during the swing (a step change in delta I rather than the expected gradual transition in a power swing).

1.14.4 Actions upon Detection of a Fault during a Power Swing

- The block signal is only removed from zones that start within 2 cycles of a fault being detected. This improves stability for external faults during power swings. Any measuring zone that was detecting an impedance within its characteristic before The phase selector detected the fault will remain blocked. This minimizes the risk of tripping for a swing impedance that may naturally be passing through Zone 1, and could otherwise cause a spurious trip if all zones were unblocked on fault inception. Any measuring zone that picks up beyond the two cycle window will remain blocked. This minimizes the risk of tripping for a continued swing that may pass through Zone 1, and could otherwise cause a spurious trip if all zones were allowed to unblock together.

1.14.5 Power Swing Settings

The power swing detection is setting free aided with slow swing detection that uses zone 5 and does not require any system study. The only setting available to a user, apart from zone 5, is to decide whether a zone should be blocked or allowed to trip after a power swing is detected. Zone by zone, it is possible to select one mode from the following:

• "**Allow Trip**"	should a power swing locus remain within a trip zone characteristic for a duration equal to the zone time delay, the trip will be allowed to happen;
• "**Blocking**"	to keep stability for that zone, even if a power swing locus should enter it;
• "**Delayed Unblock**"	maintains the block for a set duration. If the swing is still present after the "**PSB Timeout Set**" window has expired, tripping is allowed as normal.

Other setting possibilities are:

- Selection of PSB as "**Indication**" only will raise an alarm, without blocking any zones.
- The *PSB Unblock Dly* function allows for any power swing block to be removed after a set period of time. For a persistent swing that does not stabilize, any

blocked zones will be made free to trip once the timer has elapsed. In setting which relays will unblock, the user should consider which relay locations are natural split points for islanding the power system.

- The *PSB Reset Delay* is a time delay on drop-off timer, which maintains the PSB detection even after the swing has apparently stabilized. It is used to ensure that where the swing current passes through a natural minimum and delta I detection might reset, that the detection does not drop out/chatter. It can thus be used to ensure a continual Power Swing indication when pole slipping (an unstable out of step condition) is in progress.

Figure 15 is a simplified logic diagram showing operation of the power swing.

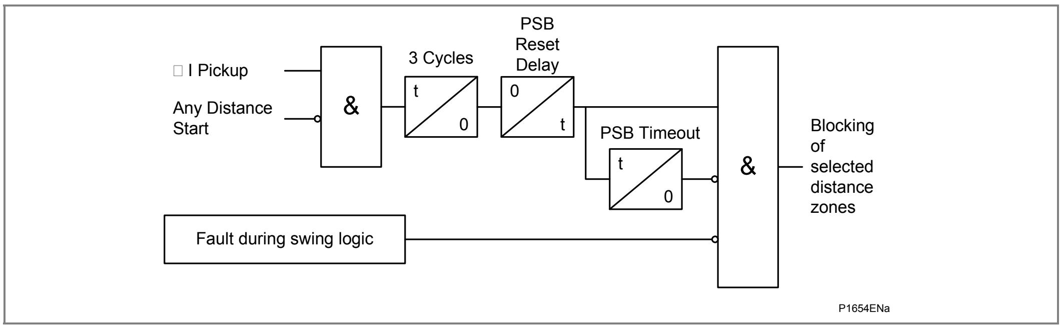


Figure 15 - Power swing blocking

1.15 Out of Step Detection and Tripping

Out of Step protection is used to split the power system into possibly stable areas of generation and load balance during unstable power oscillations. The points at which the system should be split are determined by detailed system stability studies.

The P443/P446 Out of Step function has 4 different setting options:

Option 1 - Disabled

Option 2 - Predictive OST

Option 3 - OST

Option 4 - Predictive OST or OST

When set '**Disabled**', Out of Step function is not operational. The P443/P446 also provides an option to split the system in advance by selecting the '**Predictive OST**' (sometimes called an early OST) in order to minimize the angle shift between two ends and aid stability in the split areas. The third setting option is to split the system on detection of the out of step condition i.e. when a pole slip occurs. The fourth option is a combination of the two.

1.15.1 Out of Step Detection

The Out of Step detection is based on the well proven $\Delta Z/\Delta t$ principle associated with two concentric polygon characteristic, as presented in Figure 16.

1.15.1.1 Characteristic

Both polygon characteristics are independent and have independent settings for their respective reactance and resistive reaches.

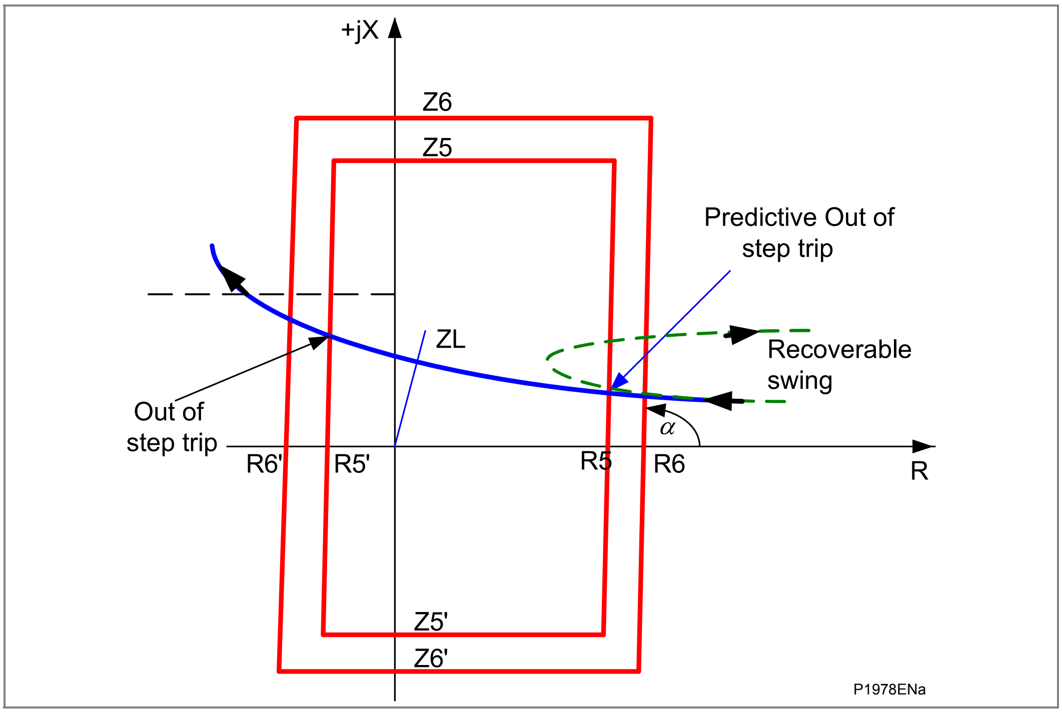


Figure 16 - Out of step detection characteristic

Note	*Both the inner (Zone 5) and outer (Zone 6) characteristics, as shown above, are settable in positive sequence impedance terms to ensure correct Out of Step detection during open pole swing conditions. Hence, there is only one Z5 and Z6 positive sequence impedance polygon characteristic instead of 6 characteristics for each measured loop. The measured positive sequence impedance is calculated as:* *Z1 = V1/I1*

Where V1 and I1 are positive sequence voltage and current derived from the measured phase quantities.

Note	*During symmetrical power oscillations, there is no difference between phase impedance loops and positive sequence impedance loop, whilst for the open pole oscillations the phase and positive sequence impedances are different. This fact must be taken into account during testing/commissioning.*

All four resistive blinders are parallel, using the common angle setting ‘**α**’ that corresponds to the angle of the total system impedance ZT (= ZS + ZL + ZR), where ZS and ZR are equivalent positive sequence impedances at the sending and receiving ends and ZL positive sequence line impedance. Tilting of the reactance line and residual compensation is not implemented.

In Figure 16, the solid impedance trajectory represents the locus for the non-recoverable power oscillation, also known as pole slip or out of step condition. The dotted impedance trajectory on the other hand represents a recoverable power oscillation, usually called swings.

1.15.1.2 Operating Principle

The Out of Step detection algorithm is based on measuring the speed of positive sequence impedance passing through the set ΔZ region. As soon as measured positive sequence impedance touches the outer polygon, a timer is started.

If the disturbance takes less than 25ms from entering zone 6 to entering zone 5, the relay will consider this to be a power system fault and not an out of step trip condition. The timer of 25ms is a fixed timer in the logic and not user accessible. During a power system fault, the speed of impedance change from a load to a fault is fast, but the relay may operate slower for marginal faults close to a zone boundary, particularly for high resistive faults inside the zone operating characteristic and close to the Z5 boundary. Therefore, the fixed time of 25ms is implemented to provide sufficient time for a distance element to operate and therefore to distinguish between a fault and an extremely fast power system oscillation.

If the disturbance takes more than 25ms but less than DeltaT set time from entering Zone 6 to entering Zone 5, this will be seen as a very fast oscillation. Therefore, the relay will trip if setting option 2 or 4 was selected. The minimum DeltaT setting is 30ms, allowing 5ms margin to the fixed 25ms timer.

If the disturbance takes longer than the DeltaT setting time to enter Zone 5 after entering Zone 6 then it is considered as a slow power oscillation. Upon entering Z5, the relay will record the polarity of the resistive part of the positive sequence impedance. Two scenarios are possible:

- If the resistive part of the positive sequence impedance leaves Z5 with the same polarity as previously recorded on entering Zone 5, it is deemed a recoverable swing. No tripping will be issued.
- If the resistive part of the positive sequence impedance has the opposite polarity when exiting Zone 5 to that of the recorded polarity on Zone 5 entering, an Out of Step condition is recognized, followed by the tripping if setting option 3 or 4 was selected. It should be noted that in the case when the DeltaT timer did not expire and setting option 3 is selected, the Out of Step condition will also be detected, followed by OST operation.

As the tripping mode for the detected Out of Step condition is always 3 ph trip, the '**Predictive OST**' and OST DDB signals are mapped to the 3ph tripping in the default PSL. Also, Out of Step operation will block auto-reclose function. The Out of Step tripping time delay TOST is also available to delay the OST tripping command until the angle between internal voltages between two ends are at 240 deg closing towards 360 deg. This is to limit the voltage stress across the circuit breaker. In the case of a fault occurring during the swing condition, the out of step tripping function will be blocked.

The Out of Step algorithm is completely independent from the distance elements and setting free power swing detection function. The load blinder does not have any effect on the OST characteristics. For the Out of Step operation, the minimum positive sequence current of 5%In must be present.

The Out of Step algorithm is given in Figure 17.

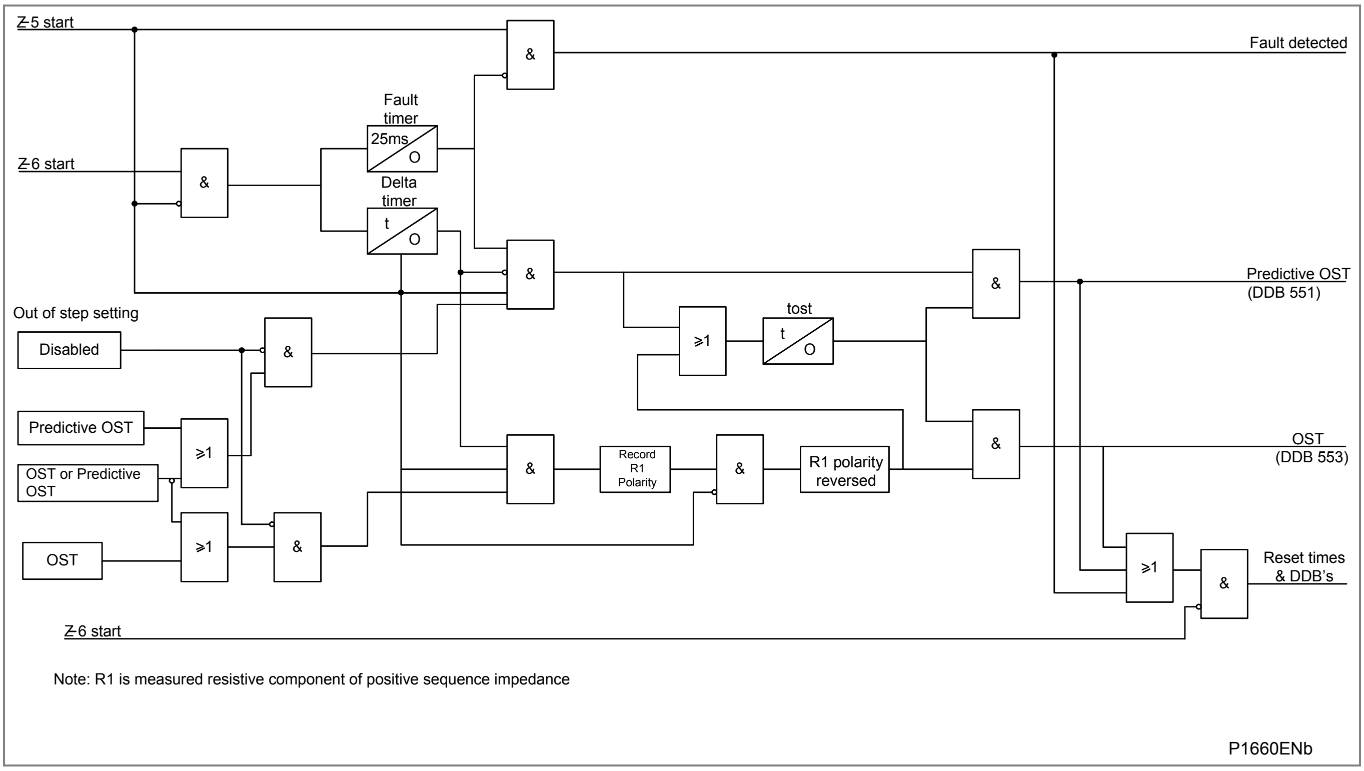

Z5 start
&
Fault detected
Fault timer
25ms
O
Z6 start
&
Delta timer
t
O
&
&
Predictive OST
(DDB 551)
Out of step setting
Disabled
&
≥1
tost
t
O
Predictive OST
≥1
OST or Predictive OST
&
Record R1 Polarity
&
R1 polarity reversed
&
OST
(DDB 553)
OST
≥1
&
≥1
&
Reset times & DDB's
Z6 start
Note: R1 is measured resistive component of positive sequence impedance
P1660ENb

Figure 17 - Out of step algorithm

1.16 Switch On To Fault (SOTF) and Trip On Reclose (TOR)

The settings for SOTF and TOR are included in the menu column “**TRIP ON CLOSE**” (TOC) within The MiCOM P443/P446 relay. The settings are designed to deal with two different scenarios.

- SOTF is designed to provide instantaneous operation of selected elements for a fault present on manual closure of the circuit breaker;
- TOR is designed to provide instantaneous operation of selected elements for a persistent fault present on auto-reclosing of the circuit breaker.

The SOTF and TOR functions are communally termed “**Trip on Close**” logic. The operation of these features is split into two Figures for clarity: Figure 18 shows Trip On Close function in relation with the Distance zones whilst Figure 19 presents Trip On Close driven by ‘**Current No Volt**’ level detectors. Both methods operate in parallel if mapped to the SOTF and TOR Tripping matrix in the setting file.

The ’**Current No Volt**’ (CNV) level detectors are user settable in the ‘**GROUP X CB FAIL & P. Dead**’ column. The same setting is used for pole dead logic detection - see Settings Section for more details. The 20ms time delay in Figure 19 is to avoid a possible race between very fast overvoltage and undercurrent level detectors.

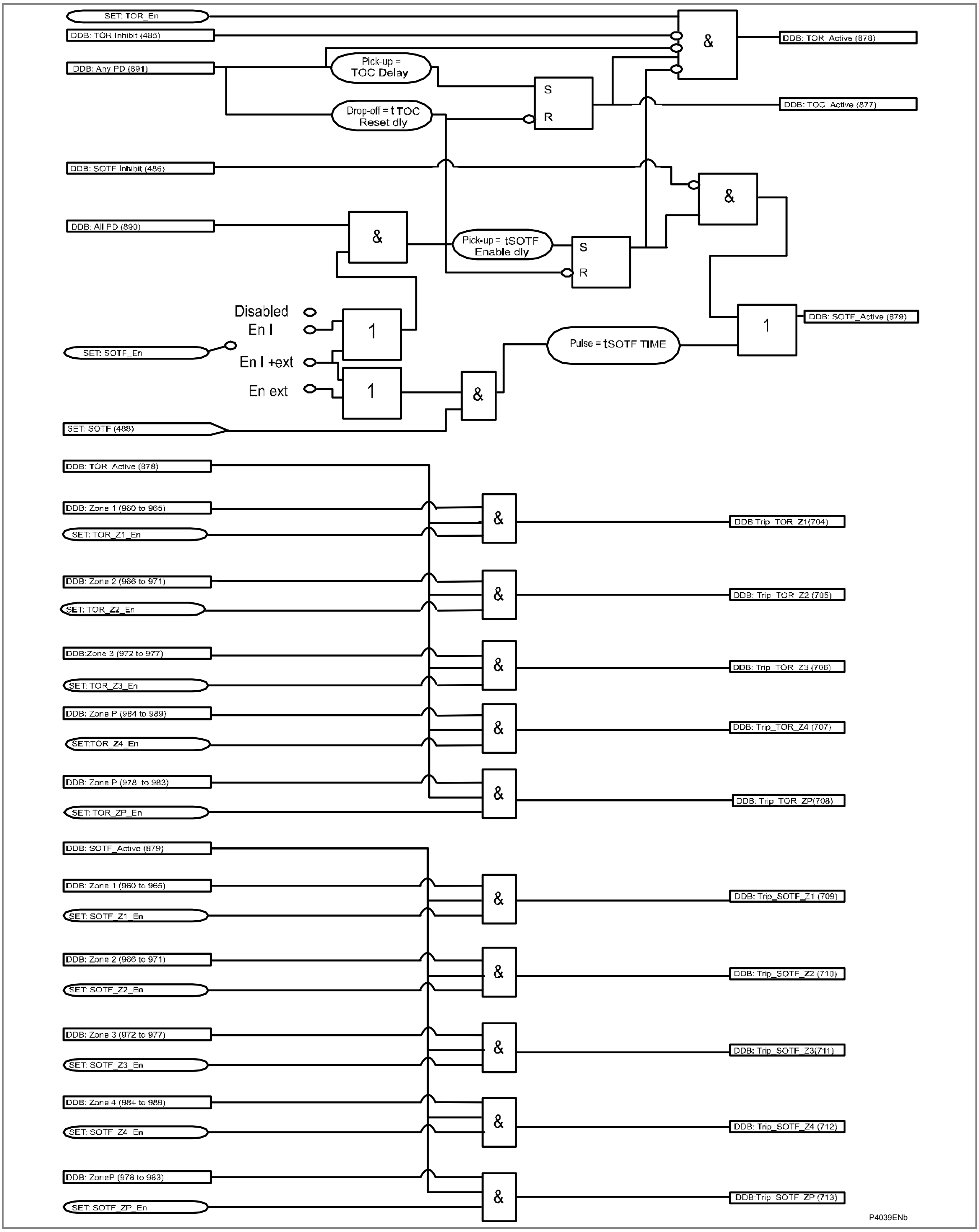

SET: TOR_En
DDB: TOR Inhibit (485)
DDB: TOR Active (878)
DDB: Any PD (891)
Pick-up = TOC Delay
Drop-off = t TOC Reset dly
S
R
DDB: TOC_Active (877)
DDB: SOTF Inhibit (486)
&
DDB: All PD (890)
&
Pick-up = tSOTF Enable dly
S
R
Disabled
En I
En I +ext
En ext
SET: SOTF_En
1
1
&
Pulse = tSOTF TIME
1
DDB: SOTF_Active (879)
SET: SOTF (488)
DDB: TOR Active (878)
DDB: Zone 1 (960 to 965)
SET: TOR_Z1_En
&
DDB Trip TOR Z1(704)
DDB: Zone 2 (966 to 971)
SET: TOR_Z2_En
&
DDB: Trip TOR Z2 (705)
DDB:Zone 3 (972 to 977)
SET: TOR_Z3_En
&
DDB: Trip TOR Z3 (706)
DDB: Zone P (984 to 989)
SET:TOR_Z4_En
&
DDB: Trip_TOR_Z4 (707)
DDB: Zone P (978 to 983)
SET: TOR_ZP_En
&
DDB: Trip_TOR_ZP(708)
DDB: SOTF_Active (879)
DDB: Zone 1 (960 to 965)
SET: SOTF_Z1_En
&
DDB: Trip_SOTF_Z1 (709)
DDB: Zone 2 (966 to 971)
SET: SOTF_Z2_En
&
DDB: Trip_SOTF_Z2 (710)
DDB: Zone 3 (972 to 977)
SET: SOTF_Z3_En
&
DDB: Trip SOTF Z3(711)
DDB: Zone 4 (984 to 989)
SET: SOTF Z4 En
&
DDB: Trip_SOTF_Z4 (712)
DDB: ZoneP (978 to 983)
SET: SOTF_ZP_En
&
DDB:Trip SOTF ZP (713)
P4039ENb

Figure 18 - Trip on close

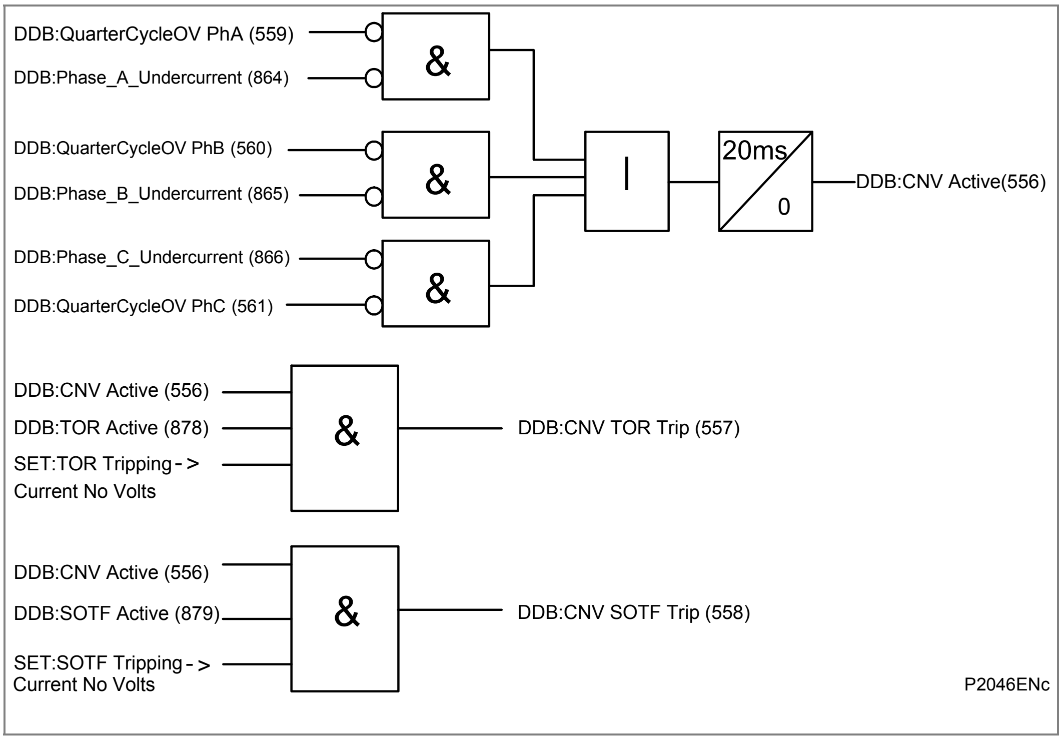

DDB:QuarterCycleOV PhA (559)
DDB:Phase_A_Undercurrent (864)
DDB:QuarterCycleOV PhB (560)
DDB:Phase_B_Undercurrent (865)
DDB:Phase_C_Undercurrent (866)
DDB:QuarterCycleOV PhC (561)
&
&
&
|
20ms
0
DDB:CNV Active(556)
DDB:CNV Active (556)
DDB:TOR Active (878)
SET:TOR Tripping-> Current No Volts
&
DDB:CNV TOR Trip (557)
DDB:CNV Active (556)
DDB:SOTF Active (879)
SET:SOTF Tripping-> Current No Volts
&
DDB:CNV SOTF Trip (558)
P2046ENc

Figure 19 - Trip on close based on CNV level detectors

1.16.1 Switch Onto Fault Mode

The settings applied are as follows:

SOTF Status	SOTF can be activated in three different manners:

3. Enabled by using pole dead logic detection logic. A ‘SOTF Delay’ timer starts if “all pole dead” condition is detected. Once this timer expires, SOTF becomes enabled and remains active during the period set on “TOC Reset Delay” setting.
4. Enabled by an external pulse. SOTF becomes enabled after an external pulse (as a circuit breaker close command for example) linked to DDB “Set SOTF” (DDB 488) is ON. The function remains active for the duration of the “SOTF Pulse” setting.
5. Enabled by using the two previous methods.

With this feature *Enabled*, the relay operates in Switch on to Fault mode. Three pole instantaneous tripping (and auto-reclose blocking) occurs for any fault detected by the selected zones or/and ‘**Current No Volt**’ level detectors when in Switch on to Fault mode. Whether this feature is enabled or disabled, the normal time delayed elements or aided channel scheme continues to function and can operate to trip the circuit.

TOC Reset Delay	The SOTF (when enabled by pole dead detection logic) and TOR features remain in-service for the duration of the TOC reset delay once the circuit is energized.
SOTF Tripping Link	While the Switch on to Fault Mode is active. The MiCOM P443/P446 will trip instantaneously for pick up of any zone selected in these links. To operate for faults on the entire circuit length it is recommended that at least Zone 1 and Zone 2 are selected. If no elements are selected then the normal time delayed elements and aided scheme provide the protection.

1.16.2 Trip on Re-Close Mode

The settings applied are as follows:

TOR Status	With this feature Enabled, for a period following circuit breaker closure, the relay operates in Trip on Re-close mode. Three pole instantaneous tripping occurs for any fault detected by the selected zones or/and '**Current No Volt**' level detectors. Whether this feature is enabled or disabled, the normal time delayed elements or aided channel scheme continue to unction and can operate to trip the circuit.
TOC Reset Delay	The SOTF and TOR features remain in-service for the duration of the TOC reset delay once the circuit is energized.
TOC Delay	Is a user settable time delay that starts upon opening the CB after which the '**TOR**' becomes active (enabled). The time delay must not exceed the minimum Dead Time setting as both times start simultaneously and TOR protection must be ready by the time of CB closing on potentially persistent faults.
TOR Tripping Links	While the Trip on Re-close Mode is active, the MiCOM P443/P446 will trip instantaneously for pick up of or/and '**Current No Volt**' level detectors any zone selected in these links. To operate for faults on the entire circuit length it is recommended that at least Zone 1 and Zone 2 are selected. If no elements are selected then the normal time delayed elements and aided scheme provide the protection.

1.16.3 Polarization during Circuit Energization

While the Switch on to Fault and Trip on Re-close modes are active, the directionalized distance elements are partially cross polarized from other phases. The same proportion of healthy phase to faulted phase voltage as given by the Distance Polarizing setting in the DISTANCE SETUP menu is used.

Partial cross polarization is thus used in substitute for the normal memory polarizing, for the duration of the TOC window. If insufficient polarizing voltage is available, a slight reverse offset (10% of the forward reach) is included in the zone 1 characteristic to enable fast clearance of close up three phase faults. Therefore, the mapping of CNV function to the SOTF tripping matrix is not essential.

1.17 Directional Function - Setup of DEF and Directional Comparison Elements

The MiCOM P443/P446 has two additional aided channel ("**pilot**") schemes that can be used to supplement the distance protection.

- DEF	Directional earth (ground) fault protection;
- Delta	∆I and ∆V based directional comparison scheme.

Both schemes are configured as unit protection, with a communication channel connected between the remote line ends.

In order to make use of these schemes, base setting data must be made in the "**GROUP x DISTANCE SETUP**" (for Delta comparison scheme) and GROUP x/AIDED DEF (For Directional earth fault protection)

1.17.1 DEF Zero Sequence Polarization with "Virtual Current Polarizing"

With earth fault protection, the polarizing (directional reference) signal requires to be representative of the earth fault condition. As residual voltage is generated during earth fault conditions, this quantity is commonly used to polarize the directional decision of DEF elements. The relay internally derives this voltage from the 3 phase voltage input which must be supplied from either a 5-limb or three single phase VTs. These types of VT design allow the passage of residual flux and consequently permit the relay to derive the required residual voltage. In addition, the primary star point of the VT must be earthed. A three-limb VT has no path for residual flux and, is therefore unsuitable to supply the relay.

It is possible that small levels of residual voltage will be present under normal system conditions due to system imbalances, VT inaccuracies, relay tolerances etc. Hence, the relay includes a user settable threshold (DEF VNPol Set) which must be exceeded in order for the DEF function to be operational.

Note	*Residual voltage is nominally 180° out of phase with residual current. Consequently, the DEF relays are polarized from the '**-Vres**' quantity. This 180° phase shift is automatically introduced within the relay.*

A distinct advantage of the MiCOM P443/P446 is that the relay can trip by this method of polarizing, even if VNpol is less than the set threshold. Provided that the superimposed current phase selector has identified the faulted phase (suppose phase A), it will remove that phase from the residual calculation Va + Vb + Vc, leaving only Vb + Vc. The resultant polarizing voltage will have a large magnitude, and will be in the same direction as –Vres. This allows the relay to be applied even where very solid earthing behind the relay prevents residual voltage from being developed.

This technique of subtracting the faulted phase is given the description "**virtual current polarizing**" as it removes the need to use current polarizing from a CT in a transformer star (wye)-ground connection behind the relay. This would have been necessary with traditional relays.

The directional criteria with zero sequence (virtual current) polarization are given below:

Directional forward

$$-90° < (\text{angle}(IN) - \text{angle}(VNpol+180°) - RCA) < 90°$$

Directional reverse

$$-90° > (\text{angle}(IN) - \text{angle}(VNpol+180°) - RCA) > 90°$$

Where VNpol is as per the table below:

Phase Selector Pickup	VNpol
A Phase Fault	VB + VC
B Phase Fault	VA + VC
C Phase Fault	VA + VB
No Selection	VN = VA + VB + VC

Table 2 - Phase Selector Pickup and VNpol

1.17.2 DEF Negative Sequence Polarization

In certain applications, the use of residual voltage polarization of DEF may either be not possible to achieve, or problematic. An example of the former case would be where a suitable type of VT was unavailable, for example if only a three-limb VT was fitted. An example of the latter case would be an HV/EHV parallel line application where problems with zero sequence mutual coupling may exist.

In either of these situations, the problem may be solved by the use of negative phase sequence (nps) quantities for polarization. This method determines the fault direction by comparison of nps voltage with nps current. The operate quantity, however, is still residual current. It requires a suitable voltage and current threshold to be set in cells '***DEF V2pol Set***' and '***DEF I2pol Set***', respectively.

The directional criteria with negative sequence polarization are given below:

Directional forward

$-90^{o} < (\text{angle}(I2) - \text{angle}(V2+180^{o}) - \text{RCA}) < 90^{o}$

Directional reverse

$-90^{o} > (\text{angle}(I2) - \text{angle}(V2+180^{o}) - \text{RCA}) > 90^{o}$

1.17.3 Delta Directional Comparison Principle and Setup

Note *The characteristic angle set in this section is also used by the DISTANCE PROTECTION. This is because distance zones are directionalized by the delta decision.*

Delta directional comparison looks at the relative phase angle of the superimposed current ΔI compared to the superimposed voltage ΔV, at the instant of fault inception. The delta is only present when a fault occurs and a step change from the pre-fault steady-state load is generated by the fault itself. The element will issue a forward or reverse decision, which can be used to input into an aided channel unit protection scheme.

Under healthy network conditions, the system voltage will be close to Vn nominal, and load current will be flowing. Under such steady-state conditions, if the voltage measured on each phase now is compared with a stored memory from exactly two power system cycles previously (equal to 96 samples), the difference between them will be zero. Zero change equals zero "**delta**" (ΔV = 0). The same will be generally true for the current (ΔI = 0), except when there are changes in load current etc.

When a fault occurs on the system, the delta changes measured will be:

ΔV = fault voltage (time "**t**") pre-fault healthy voltage (t-96 samples)

ΔI = fault current (time "**t**") pre-fault load current (t-96 samples)

The delta measurements are a vector difference, resulting in a delta magnitude and angle. Under healthy system conditions, the pre-fault values will be those measured 2 cycles earlier, but when a fault is detected, the pre-fault values will be retained for the duration of the fault.

The changes in magnitude are used to detect the presence of the fault, and the angles are used to determine whether the fault is in the Forward or Reverse direction.

Consider a single phase to ground fault as shown in Figure 20.

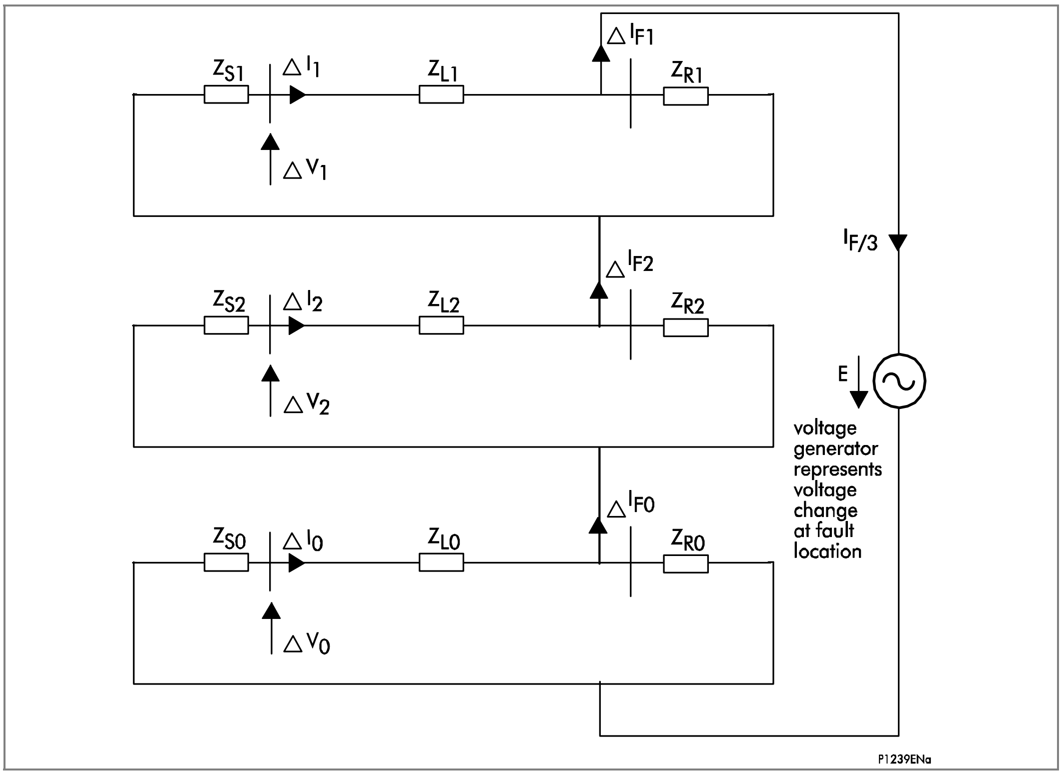


Figure 20 - Sequence networks connection for an internal A-N fault

The fault is shown near to the busbar at end R of the line, and results in a connection of the positive, negative, and zero sequence networks in series. Drawing the delta diagram, it is seen that any fault is effectively a generator of Δ, connected at the location of fault inception. The characteristics are:

1. The ΔI generated by the fault is equal to the total fault arc current;
2. The ΔI will split into parallel paths, with part contribution from source "**S**", and part from remote end "**R**" of the line. Therefore, each relay will measure a lower proportion of delta I;
3. The ΔV generated by the fault is equal to the fault arc voltage minus the pre-fault voltage (and so will be in anti-phase with the pre-fault voltage);
4. The ΔV will generally be smaller as measured at the relay location, due to the voltage collapse being smaller near to the source than at the fault itself. The delta V measured by a relay is effectively the voltage drop across the source impedance behind the relay location.

If a fault were to occur at any point on the protected line, the resulting ΔI and ΔV as measured at the relay location must be greater than the "***DeltaIFwd***" and "***Delta V Fwd***" settings, in order that the fault can be detected. (Scenarios (2) and (4) above must be verified for all fault types: Ph-G, Ph-Ph, Ph-Ph-G, and 3-phase)

1.17.4 Delta Directional decision

On fault inception, delta quantities are generated, and it is then simple for the relay to determine the direction of the fault:

Forward fault	Delta V is a decrease in voltage, and so is in the negative sense; whereas delta I is a forward current flow and so is in the positive sense. Where delta I and delta V are approximately in anti-phase, the fault is forward. The exact angle relationship for the forward fault is: $\Delta V/\Delta I = -(\text{Source impedance, Zs})$
Reverse fault	Delta V is a decrease in voltage, and so is in the negative sense; delta I is an outfeed flowing in the reverse direction, so that too is in the negative sense. Where delta I and delta V are approximately in phase, the fault is reverse. The exact angle relationship for the reverse fault is: $\Delta V/\Delta I = (\text{Remote Source impedance Zs'} + \text{ZL})$

Where ZL is protected line impedance and Zs' source impedance behind the relay.

An RCA angle setting in the relay allows the user to set the center of the directional characteristic, according to the amount the current will nominally lag the reference delta voltage. The characteristic boundary will then be ± 90 degrees either side of the set center.

Note *Distance zone directionalizing shares the same characteristic angle setting used for Delta directional comparison protection, but uses fixed operating thresholds: $\Delta V=0.5V$ and $\Delta I=4\%In$. In distance applications, if the fault ΔV is below the setting of 0.5V, a conventional distance line ensures correct forward/reverse polarizing. This is not true for Delta directional aided schemes where sufficient ΔV must be present, for tripping to occur.*

The directional criteria for delta directional decisions are given below:

Directional forward

$$-90o < (\text{angle}(\Delta I) - \text{angle}(\Delta V+180^{o}) - \text{RCA}) < 90^{o}$$

Directional reverse

$$-90^{o} > (\text{angle}(\Delta I) - \text{angle}(\Delta V+180^{o}) - \text{RCA}) > 90^{o}$$

In order to facilitate testing of the Distance elements using test sets which do not provide a dynamic model to generate true fault delta conditions, a Static Test Mode setting is provided. This setting is found in the COMMISSIONING TESTS menu column. When set, this disables phase selector control and forces the relay to use a conventional (non-delta) directional line.

1.18 Channel Aided Schemes

The MiCOM P443/P446 offers two sets of aided channel (“**pilot**”) schemes, which may be operated in parallel.

Aided Scheme 1 -	May be keyed by distance and/or DEF and/or delta directional comparison;
Aided Scheme 2 -	May be keyed by distance and/or DEF and/or delta directional comparison;

The provision of two discrete channel selections would allow the following to be implemented, as an example:

- Distance POR with DEF POR scheme operating over a common shared channel… Select both in AIDED SCHEME 1 only, with AIDED SCHEME 2 “**Disabled**”.
- Distance PUR with DEF BLOCKING operating over separate channels due to the dissimilar scheme types… Assign Distance to AIDED SCHEME 1, and DEF to AIDED SCHEME 2.
- Directional Comparison BLOCKING scheme with a second channel for a distance with DEF BLOCKING scheme operating in unison… Assign “**Delta**” to AIDED SCHEME 1, and both Distance/DEF to AIDED SCHEME 2.

Note *Where schemes share a common channel, the signal send and signal receive logic operates in a logical “**OR**” mode.*

Aided Scheme 1 and Aided Scheme 2 are two instances of the same logic. Each of these schemes provides the same options and can be independently applied. The scheme logic is split into three sections defined in the following diagram: send logic, receive logic, and aided tripping logic, as shown in Figure 21. Detailed scheme descriptions follow later. As there are two instances of the aided scheme, any internal logic signals which are specific to the instance of the scheme are shown in the diagrams with two DDB numbers relating to the first and second instance, respectively.

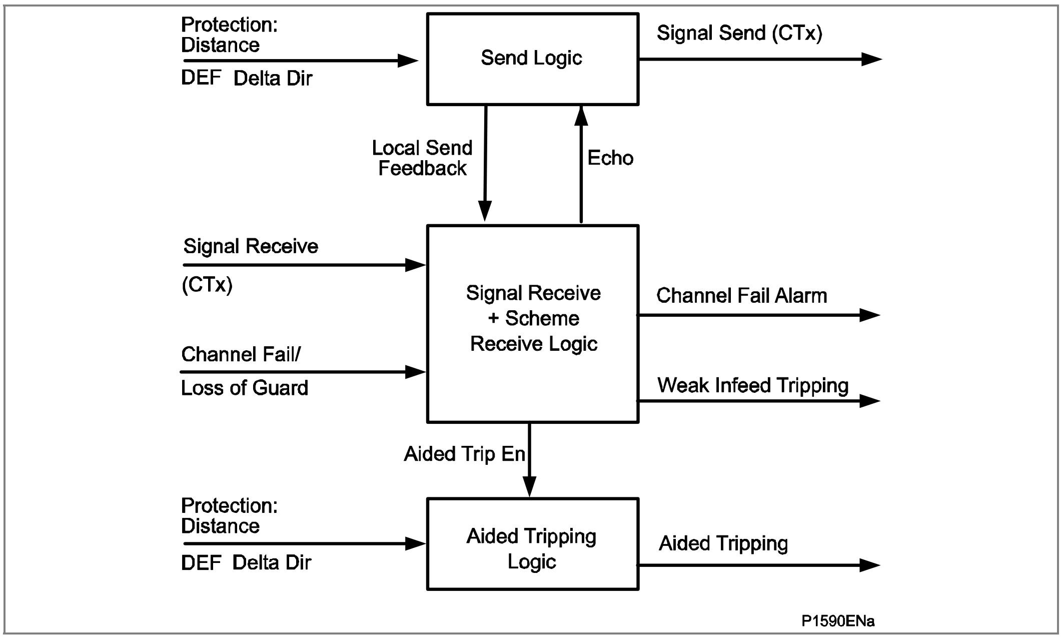

Protection:
Distance
DEF Delta Dir
Send Logic
Signal Send (CTx)
Local Send Feedback
Echo
Signal Receive
(CTx)
Signal Receive + Scheme Receive Logic
Channel Fail Alarm
Channel Fail/
Loss of Guard
Weak Infeed Tripping
Aided Trip En
Protection:
Distance
DEF Delta Dir
Aided Tripping Logic
Aided Tripping
P1590ENa

Figure 21 - Aided scheme logic overview

The full Logic Diagrams of the Send, Receive and Aided Trip Logic are now attached here, for reference. It is not necessary to understand the entire logic in order to apply any scheme, as in later sections abbreviated scheme diagrams are available.

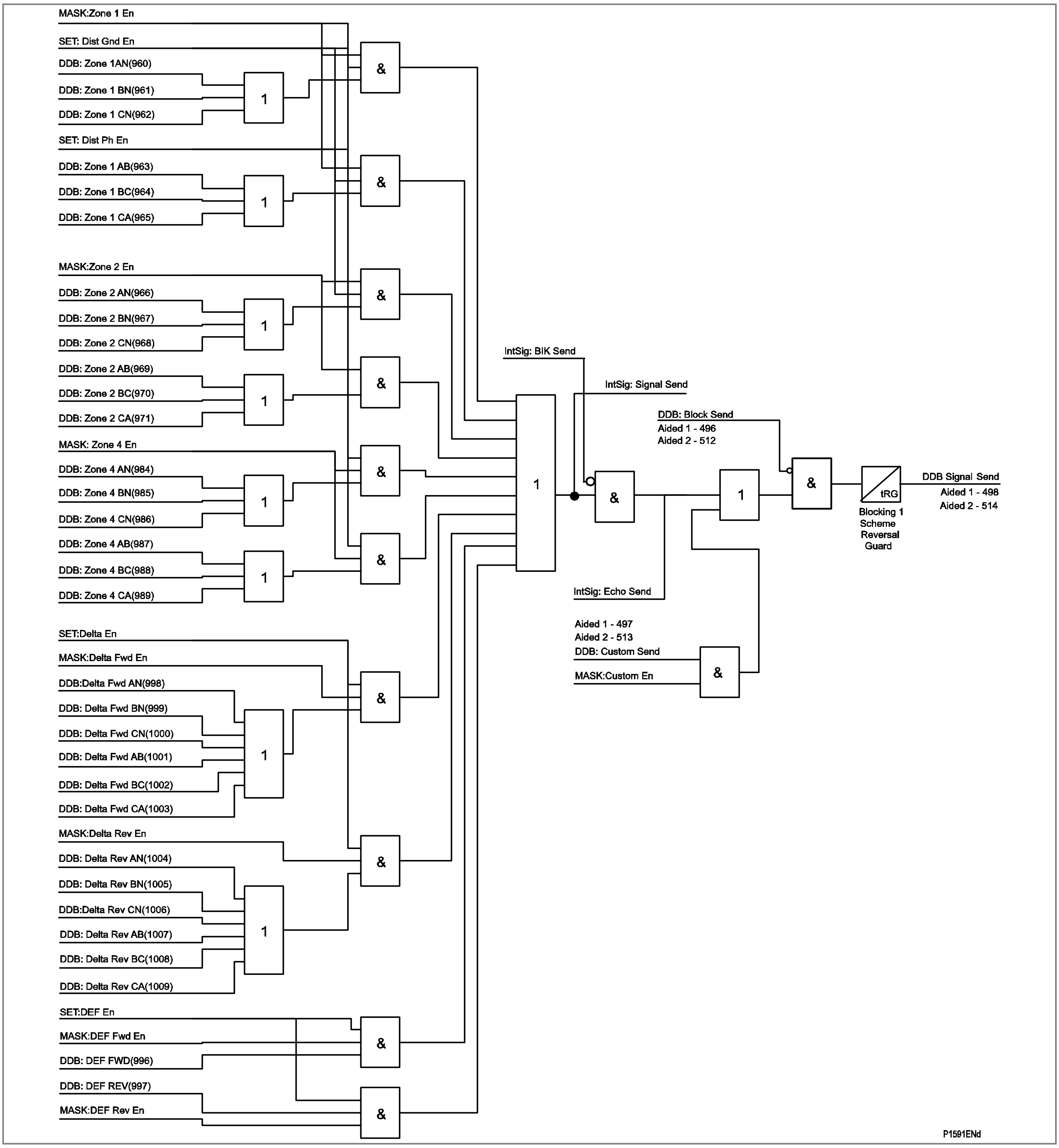

MASK:Zone 1 En
SET: Dist Gnd En
DDB: Zone 1AN(960)
DDB: Zone 1 BN(961)
DDB: Zone 1 CN(962)
SET: Dist Ph En
DDB: Zone 1 AB(963)
DDB: Zone 1 BC(964)
DDB: Zone 1 CA(965)
MASK:Zone 2 En
DDB: Zone 2 AN(966)
DDB: Zone 2 BN(967)
DDB: Zone 2 CN(968)
DDB: Zone 2 AB(969)
DDB: Zone 2 BC(970)
DDB: Zone 2 CA(971)
MASK: Zone 4 En
DDB: Zone 4 AN(984)
DDB: Zone 4 BN(985)
DDB: Zone 4 CN(986)
DDB: Zone 4 AB(987)
DDB: Zone 4 BC(988)
DDB: Zone 4 CA(989)
SET:Delta En
MASK:Delta Fwd En
DDB:Delta Fwd AN(998)
DDB: Delta Fwd BN(999)
DDB: Delta Fwd CN(1000)
DDB: Delta Fwd AB(1001)
DDB: Delta Fwd BC(1002)
DDB: Delta Fwd CA(1003)
MASK:Delta Rev En
DDB: Delta Rev AN(1004)
DDB: Delta Rev BN(1005)
DDB:Delta Rev CN(1006)
DDB: Delta Rev AB(1007)
DDB: Delta Rev BC(1008)
DDB: Delta Rev CA(1009)
SET:DEF En
MASK:DEF Fwd En
DDB: DEF FWD(996)
DDB: DEF REV(997)
MASK:DEF Rev En
&
1
IntSig: BIK Send
IntSig: Signal Send
DDB: Block Send
Aided 1 - 496
Aided 2 - 512
IntSig: Echo Send
Aided 1 - 497
Aided 2 - 513
DDB: Custom Send
MASK:Custom En
tRG
Blocking 1 Scheme Reversal Guard
DDB Signal Send
Aided 1 - 498
Aided 2 - 514
P1591ENd

Figure 22 - Send logic

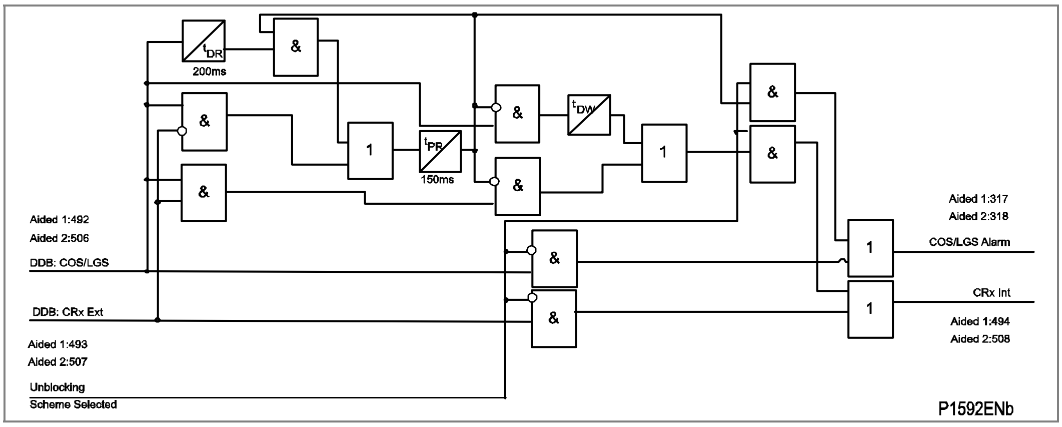

tDR
200ms
tPR
150ms
tDW
Aided 1:492
Aided 2:506
DDB: COS/LGS
DDB: CRx Ext
Aided 1:493
Aided 2:507
Unblocking
Scheme Selected
Aided 1:317
Aided 2:318
COS/LGS Alarm
CRx Int
Aided 1:494
Aided 2:508
P1592ENb

Figure 23 - Receive logic

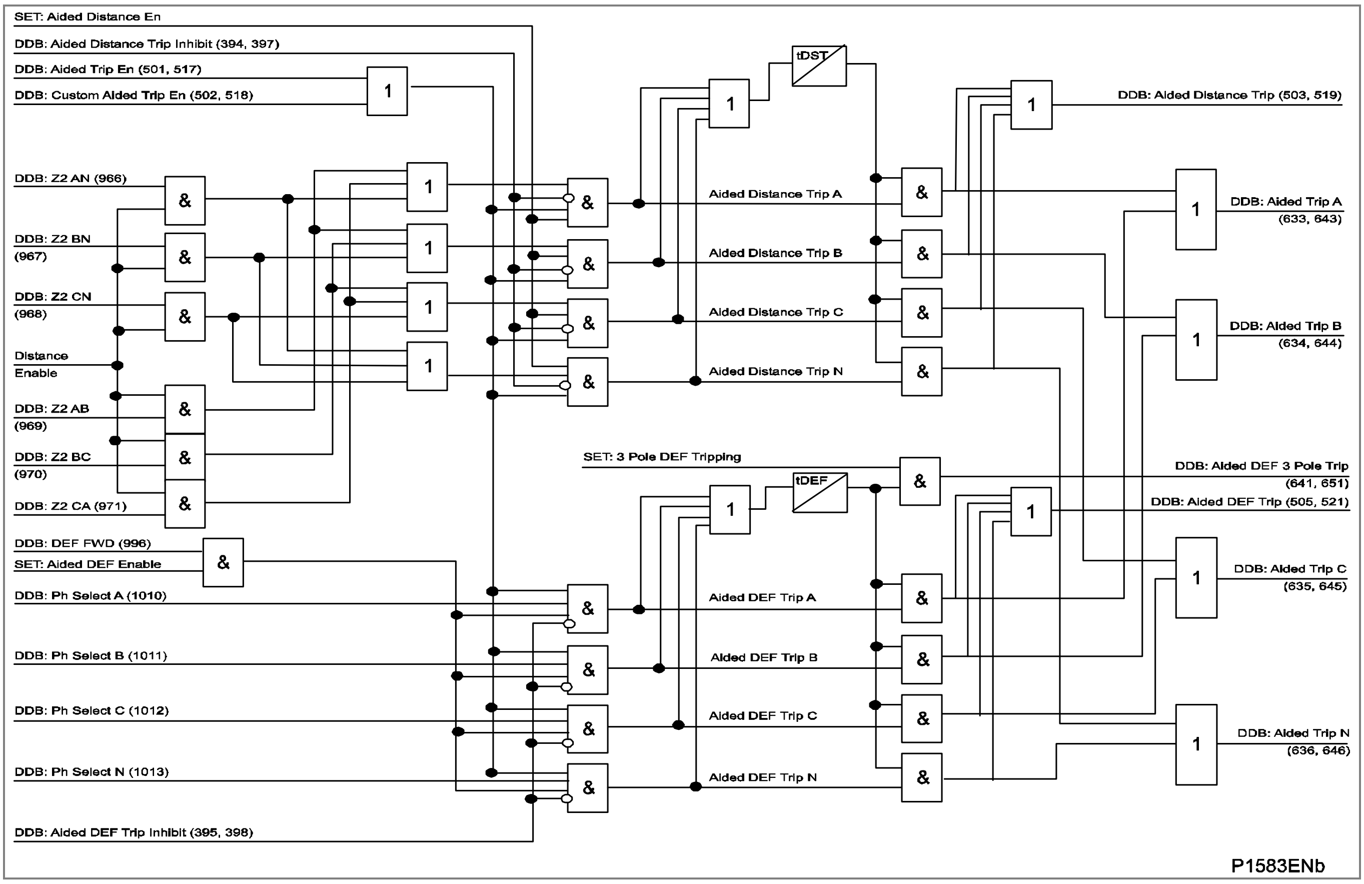

SET: Aided Distance En
DDB: Aided Distance Trip Inhibit (394, 397)
DDB: Aided Trip En (501, 517)
DDB: Custom Aided Trip En (502, 518)
DDB: Z2 AN (966)
DDB: Z2 BN (967)
DDB: Z2 CN (968)
Distance Enable
DDB: Z2 AB (969)
DDB: Z2 BC (970)
DDB: Z2 CA (971)
DDB: DEF FWD (996)
SET: Aided DEF Enable
DDB: Ph Select A (1010)
DDB: Ph Select B (1011)
DDB: Ph Select C (1012)
DDB: Ph Select N (1013)
DDB: Aided DEF Trip Inhibit (395, 398)
tDST
tDEF
Aided Distance Trip A
Aided Distance Trip B
Aided Distance Trip C
Aided Distance Trip N
SET: 3 Pole DEF Tripping
Aided DEF Trip A
Aided DEF Trip B
Aided DEF Trip C
Aided DEF Trip N
DDB: Aided Distance Trip (503, 519)
DDB: Aided Trip A (633, 643)
DDB: Aided Trip B (634, 644)
DDB: Aided DEF 3 Pole Trip (641, 651)
DDB: Aided DEF Trip (505, 521)
DDB: Aided Trip C (635, 645)
DDB: Aided Trip N (636, 646)
P1583ENb

Figure 24 - Aided tripping logic

1.18.1 Distance Scheme PUR - Permissive Underreach Transfer Trip

To provide fast fault clearance for all faults, both transient and permanent, along the length of the protected circuit, it is necessary to use a signal aided tripping scheme. The simplest of these is the Permissive UnderReach (PUR) protection scheme. The channel for a PUR scheme is keyed by operation of the underreaching zone 1 elements of the relay. If the remote relay has detected a forward fault upon receipt of this signal, the relay will operate with no additional delay. Faults in the last 20% (Note 1) of the protected line are therefore cleared with no intentional time delay.

*Note 1: Assuming a 20% typical "**end-zone**" when Zone 1 is set to 80% of the protected line.*

Listed below are some of the main features/requirements for a permissive underreaching scheme:

- Only a simplex signaling channel is required
- The scheme has a high degree of security since the signaling channel is only keyed for faults within the protected line
- If the remote terminal of a line is open then faults in the remote 20% of the line will be cleared via the zone 2 time delay of the local relay
- If there is a weak or zero infeed from the remote line end, (i.e. current below the relay sensitivity), then faults in the remote 20% of the line will be cleared via the zone 2 time delay of the local relay
- If the signaling channel fails, Basic distance scheme tripping will be available

Figure 25 shows the simplified scheme logic.

Send logic: Zone 1

Permissive trip logic: Zone 2 plus Channel Received

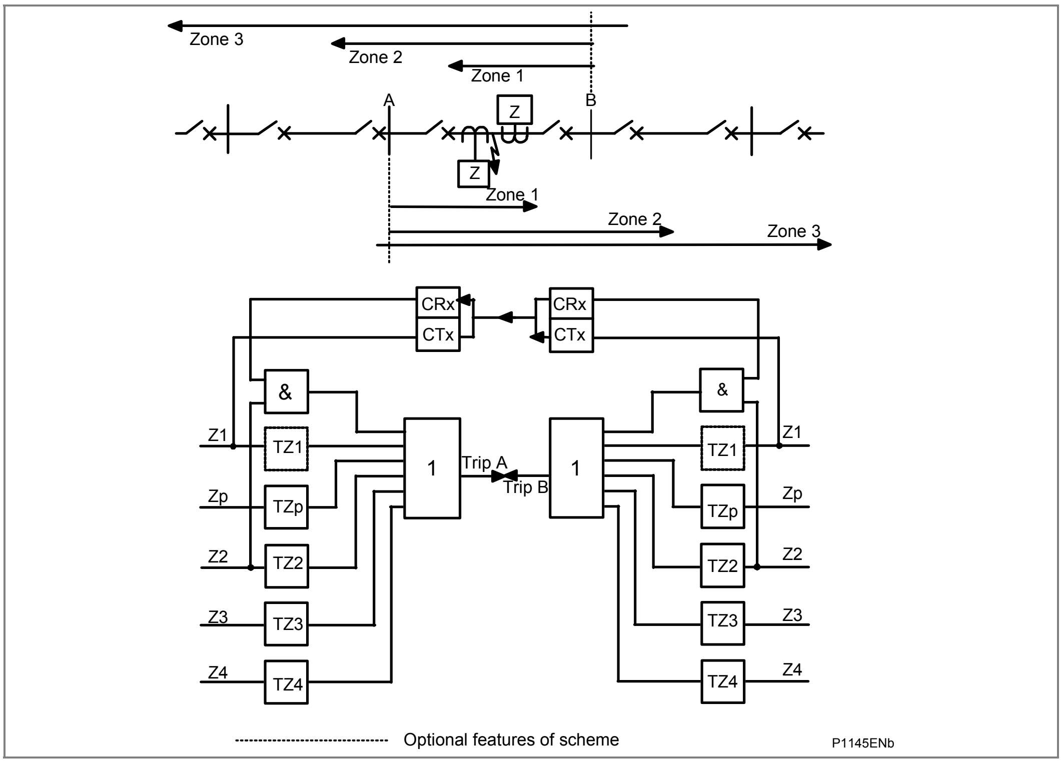

Zone 3
Zone 2
Zone 1
A
B
Z
Z
Zone 1
Zone 2
Zone 3
CRx
CTx
CRx
CTx
&
&
Z1
TZ1
Zp
TZp
Z2
TZ2
Z3
TZ3
Z4
TZ4
1
Trip A
Trip B
1
Z1
TZ1
Zp
TZp
Z2
TZ2
Z3
TZ3
Z4
TZ4
Optional features of scheme
P1145ENb

Figure 25 - Permissive underreach transfer trip scheme (PUR)

Detailed logic is shown in Figure 26, as follows:

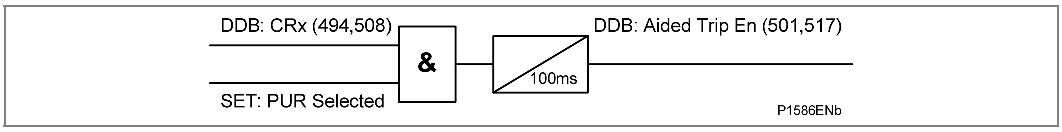

DDB: CRx (494,508)
SET: PUR Selected
&
100ms
DDB: Aided Trip En (501,517)
P1586ENb

Figure 26 - PUR

1.18.2 Distance Scheme POR - Permissive Overreach Transfer Trip

The channel for a POR scheme is keyed by operation of the overreaching zone 2 elements of the relay. If the remote relay has detected a forward fault upon receipt of this signal, the relay will operate with no additional delay. Faults in the last 20% (Note 1) of the protected line are therefore cleared with no intentional time delay.

Note 1:	*Assuming a 20% typical "**end-zone**" when Zone 1 is set to 80% of the protected line.*

Listed below are some of the main features/requirements for a permissive overreaching scheme:

- The scheme requires a duplex signaling channel to prevent possible relay mal-operation due to spurious keying of the signaling equipment. This is necessary due to the fact that the signaling channel is keyed for faults external to the protected line.
- The POR scheme may be more advantageous than permissive underreach schemes for the protection of short transmission lines, since the resistive coverage of the Zone 2 elements may be greater than that of the Zone 1 elements.
- Current reversal guard logic is used to prevent healthy line protection mal-operation for the high speed current reversals experienced in double circuit lines, caused by sequential opening of circuit breakers.
- If the signaling channel fails, Basic distance scheme tripping will be available.

Note	*The POR scheme also uses the reverse looking zone 4 of the relay as a reverse fault detector. This is used in the current reversal logic and in the optional weak infeed echo feature, shown dotted in 0.*

Send logic: Zone 2

Permissive trip logic: Zone 2 plus Channel Received

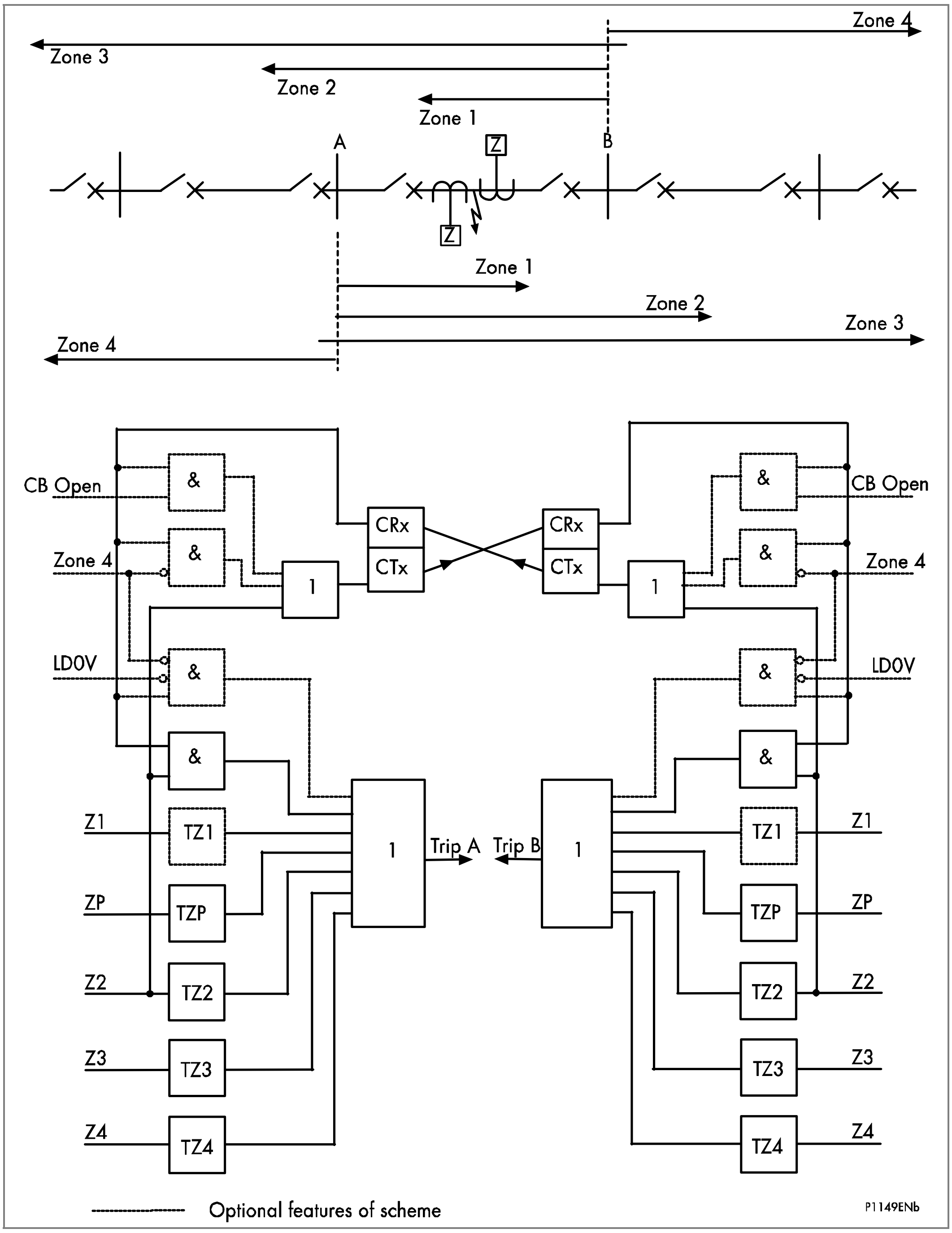

Zone 4
Zone 3
Zone 2
Zone 1
A
B
Z
Z
Zone 1
Zone 2
Zone 3
Zone 4
CB Open
Zone 4
LDOV
&
CRx
CTx
1
Z1
ZP
Z2
Z3
Z4
TZ1
TZP
TZ2
TZ3
TZ4
Trip A
Trip B
Optional features of scheme
P1149ENb

Figure 27 - Permissive overreach transfer trip scheme (POR)

Detailed logic is shown in Figure 28. It should be noted that the DDB "**Any Trip**" (522) feeds into a 100ms delay on drop-off timer, which in turn leads to signal sending. This is a principle similar to the logic which results in a signal send for weak infeed and breaker open echoing.

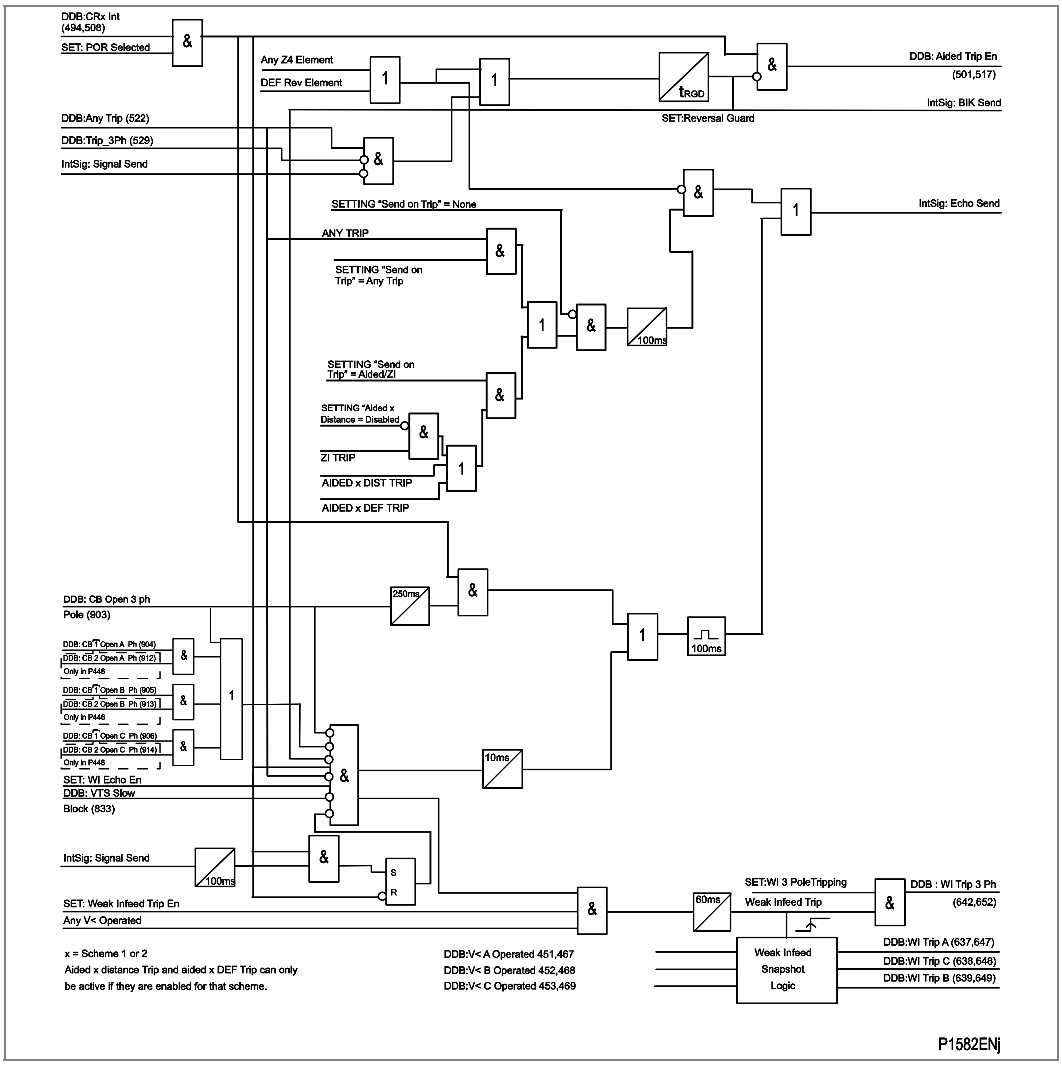

DDB:CRx Int
(494,508)
SET: POR Selected
&
Any Z4 Element
DEF Rev Element
1
1
tRGD
SET:Reversal Guard
&
DDB: Aided Trip En
(501,517)
IntSig: BIK Send
DDB:Any Trip (522)
DDB:Trip_3Ph (529)
IntSig: Signal Send
&
&
1
IntSig: Echo Send
SETTING "Send on Trip" = None
ANY TRIP
&
SETTING "Send on Trip" = Any Trip
1
&
100ms
SETTING "Send on Trip" = Aided/ZI
&
SETTING "Aided x Distance = Disabled
&
ZI TRIP
1
AIDED x DIST TRIP
AIDED x DEF TRIP
&
250ms
DDB: CB Open 3 ph
Pole (903)
1
100ms
DDB: CB 1 Open A Ph (904)
DDB: CB 2 Open A Ph (912)
Only in P446
&
DDB: CB 1 Open B Ph (905)
DDB: CB 2 Open B Ph (913)
Only in P446
&
1
DDB: CB 1 Open C Ph (906)
DDB: CB 2 Open C Ph (914)
Only in P446
&
&
10ms
SET: WI Echo En
DDB: VTS Slow
Block (833)
IntSig: Signal Send
100ms
&
S
R
SET: Weak Infeed Trip En
Any V< Operated
&
60ms
SET:WI 3 PoleTripping
Weak Infeed Trip
&
DDB : WI Trip 3 Ph
(642,652)
x = Scheme 1 or 2
Aided x distance Trip and aided x DEF Trip can only
be active if they are enabled for that scheme.
DDB:V< A Operated 451,467
DDB:V< B Operated 452,468
DDB:V< C Operated 453,469
Weak Infeed
Snapshot
Logic
DDB:WI Trip A (637,647)
DDB:WI Trip C (638,648)
DDB:WI Trip B (639,649)
P1582ENj

Figure 28 - POR

1.18.3 Permissive Overreach Trip Reinforcement

The send logic in the POR scheme is done in such a way that for any trip command at the local end, the relay sends a channel signal to the remote end(s) in order to maximize the chances for the fault to be isolated at all ends. It should be noted that the send signal that is generated by the '**Any trip**' command is sent on both channels, Ch1 and Ch2, if more then one channel is in use. This feature is termed "**permissive trip reinforcement**", and is a deliberate attempt to ensure that synchronous tripping occurs at all line ends.

1.18.4 Permissive Overreach Scheme Weak Infeed Features

Weak infeed logic can be enabled to run in parallel with the POR schemes. Two options are available: WI Echo, and WI Tripping.

Note	*Special stub-end transformer Weak Infeed is covered in section 1.37.*

<ins>Weak Infeed Echo</ins> For permissive schemes, a signal would only be sent if the required signal send zone were to detect a fault. However, the fault current infeed at one line end may be so low as to be insufficient to operate any distance zones, and risks a failure to send the signal.

Also, if one circuit breaker had already been left open, the current infeed would be zero. These are termed weak infeed conditions, and may result in slow fault clearance at the strong infeed line end (tripping after time tZ2). To avoid this slow tripping, the weak infeed relaycan be set to "**echo**" back any channel received to the strong infeed relay (i.e. to immediately send a signal once a signal has been received). This allows the strong infeed relay to trip instantaneously in its permissive trip zone.

The additional signal send logic is:

Echo Send	No Distance Zone Operation, plus Channel Received.
Weak Infeed Tripping	Weak infeed echo logic ensures an aided trip at the strong infeed terminal but not at the weak infeed. The MiCOM P443/P446 also has a setting option to allow tripping of the weak infeed circuit breaker of a faulted line. Three undervoltage elements, Va<, Vb< and Vc< are used to detect the line fault at the weak infeed terminal. This voltage check prevents tripping during spurious operations of the channel or during channel testing. The additional weak infeed trip logic is:
Weak Infeed Trip	No Distance Zone Operation, plus V<, plus Channel Received.

Weak infeed tripping is time delayed according to the "**WI Trip Delay**" value. Due to the use of phase segregated undervoltage elements, single pole tripping can be enabled for WI trips if required. If single pole tripping is disabled a three pole trip will result after the time delay.

1.18.5 Permissive Scheme Unblocking Logic - Loss of Guard

This mode is designed for use with frequency shift keyed (FSK) power line carrier communications. When the protected line is healthy a guard frequency is sent between line ends, to verify that the channel is in service. However, when a line fault occurs and a permissive trip signal must be sent over the line, the power line carrier frequency is shifted to a new (trip) frequency. Thus, distance relays should receive either the guard, or trip frequency, but not both together. With any permissive scheme, the PLC communications are transmitted over the power line which may contain a fault. So, for certain fault types the line fault can attenuate the PLC signals, so that the permissive signal is lost and not received at the other line end. To overcome this problem, when the guard is lost and no "**trip**" frequency is received, the relay opens a window of time during which the permissive scheme logic acts as though a "**trip**" signal had been received. Two opto inputs to the relay need to be assigned, one is the Channel Receive opto, the second is designated Loss of Guard (the inverse function to guard received). The function logic is summarized in Table 3.

System Condition	Permissive Channel Received	Loss of Guard	Permissive Trip Allowed	Alarm Generated
Healthy Line	No	No	No	No
Internal Line Fault	Yes	Yes	Yes	No
Unblock	No	Yes	Yes, during a 150ms window	Yes, delayed on pickup by 150ms
Signaling Anomaly	Yes	No	No	Yes, delayed on pickup by 150ms

Table 3 - Function log

The window of time during which the unblocking logic is enabled starts 10ms after the guard signal is lost, and continues for 150ms. The 10ms delay gives time for the signaling equipment to change frequency as in normal operation. For the duration of any alarm condition, zone 1 extension logic will be invoked if the option *Z1 Ext on Chan. Fail* has been Enabled.

1.18.6 Distance Scheme Blocking

The signaling channel is keyed from operation of the reverse zone 4 elements of the relay. If the remote relay has picked up in zone 2, then it will operate after the trip delay if no block is received. Listed below are some of the main features/requirements for a BLOCKING scheme:

- BLOCKING schemes require only a simplex signaling channel
- Reverse looking Zone 4 is used to send a blocking signal to the remote end to prevent unwanted tripping
- When a simplex channel is used, a BLOCKING scheme can easily be applied to a
- multi-terminal line provided that outfeed does not occur for any internal faults
- The blocking signal is transmitted over a healthy line, and so there are no problems associated with power line carrier signaling equipment
- BLOCKING schemes provides similar resistive coverage to the permissive overreach schemes
- Fast tripping will occur at a strong source line end, for faults along the protected line section, even if there is weak or zero infeed at the other end of the protected line
- If a line terminal is open, fast tripping will still occur for faults along the whole of the protected line length
- If the signaling channel fails to send a blocking signal during a fault, fast tripping will occur for faults along the whole of the protected line, but also for some faults within the next line section
- If the signaling channel is taken out of service, the relay will operate in the conventional basic mode
- A current reversal guard timer is included in the signal send logic to prevent unwanted trips of the relay on the healthy circuit, during current reversal situations on a parallel circuit

Figure 29 shows the simplified scheme logic.

Send logic: Reverse Zone 4

Trip logic: Zone 2, plus Channel NOT Received, delayed by Tp

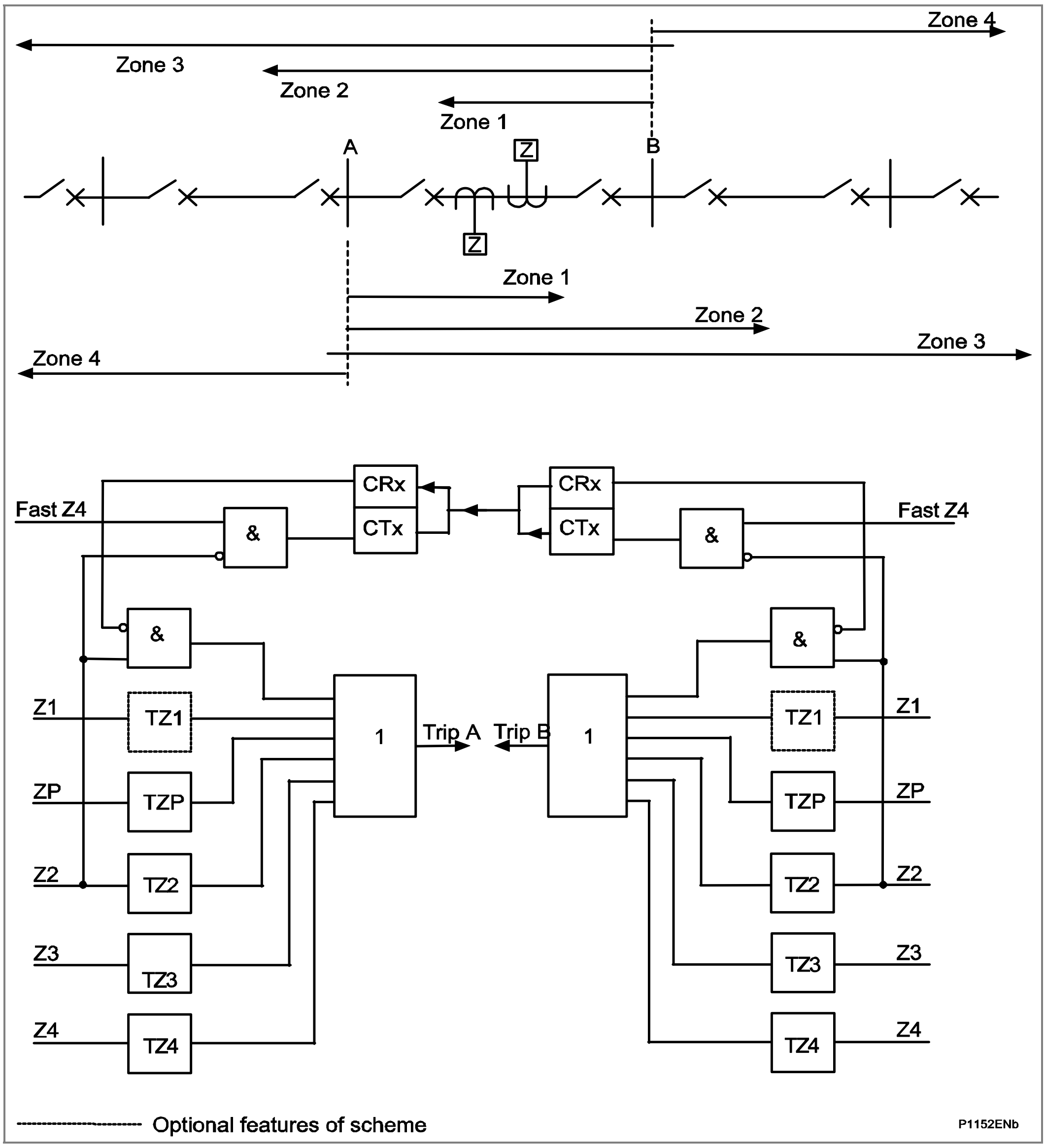

Zone 4
Zone 3
Zone 2
Zone 1
A
B
Z
Z
Zone 1
Zone 2
Zone 3
Zone 4
CRx
CTx
CRx
CTx
Fast Z4
Fast Z4
&
&
&
&
Z1
TZ1
ZP
TZP
Z2
TZ2
Z3
TZ3
Z4
TZ4
1
Trip A
Trip B
1
Z1
TZ1
ZP
TZP
Z2
TZ2
Z3
TZ3
Z4
TZ4
Optional features of scheme
P1152ENb

Figure 29 - Distance blocking scheme (BOP)

1.18.7 Distance Schemes Current Reversal Guard Logic

For double circuit lines, the fault current direction can change in one circuit when circuit breakers open sequentially to clear the fault on the parallel circuit. The change in current direction causes the overreaching distance elements to see the fault in the opposite direction to the direction in which the fault was initially detected (settings of these elements exceed 150% of the line impedance at each terminal). The race between operation and resetting of the overreaching distance elements at each line terminal can cause the Permissive Overreach, and Blocking schemes to trip the healthy line. A system configuration that could result in current reversals is shown in Figure 30. For a fault on line L1 close to circuit breaker B, as circuit breaker B trips it causes the direction of current flow in line L2 to reverse.

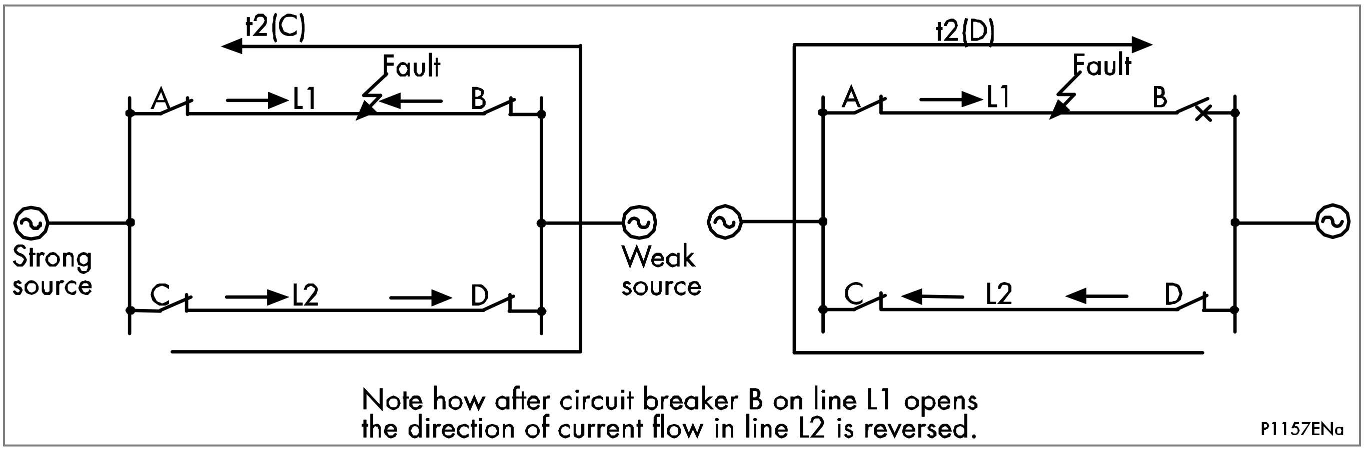

t2(C)
Fault
A
L1
B
Strong source
C
L2
D
Weak source
t2(D)
Fault
A
L1
B
C
L2
D
Note how after circuit breaker B on line L1 opens the direction of current flow in line L2 is reversed.
P1157ENa

Figure 30 - Example of fault current reverse of direction

1.18.8 Permissive Overreach Schemes Current Reversal Guard

The current reversal guard incorporated in the POR scheme logic is initiated when the reverse looking Zone 4 elements operate on a healthy line. Once the reverse looking Zone 4 elements have operated, the relay's permissive trip logic and signal send logic are inhibited at substation D. The reset of the current reversal guard timer is initiated when the reverse looking Zone 4 resets. A time delay tREVERSAL GUARD is required in case the overreaching trip element at end D operates before the signal send from the relay at end C has reset. Otherwise this would cause the relay at D to over trip. Permissive tripping for the relays at D and C substations is enabled again, once the faulted line is isolated and the current reversal guard time has expired.

1.18.9 Blocking Scheme 1 and 2 Current Reversal Guard

The current reversal guard incorporated in the BLOCKING scheme logic is initiated when a blocking element picks-up to inhibit the channel-aided trip. When the current reverses and the reverse looking Zone 4 elements reset, the blocking signal is maintained by the timer tREVERSAL GUARD. Thus, the relays in the healthy line are prevented from over tripping due to the sequential opening of the circuit breakers in the faulted line. After the faulted line is isolated, the reverse-looking Zone 4 elements at substation C and the forward looking elements at substation D will reset.

Two variants of Blocking scheme exist, BLOCKING 1, and BLOCKING 2. The only difference in functionality is:

- BLOCKING 1 - The Reversal Guard is applied to the Signal Send
- BLOCKING 2 - The Reversal Guard is applied to the Signal Receive

The difference in the receive logic is shown in Logic Diagrams, Figure 31 and Figure 32 below:

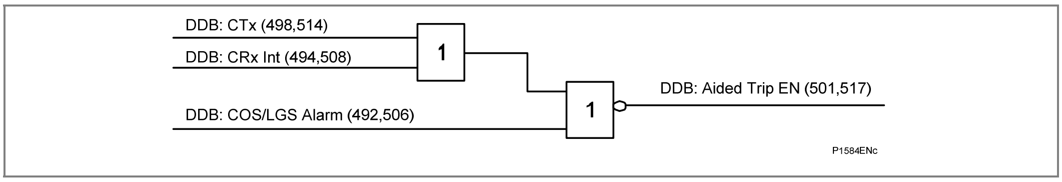

DDB: CTx (498,514)
DDB: CRx Int (494,508)
1
DDB: COS/LGS Alarm (492,506)
1
DDB: Aided Trip EN (501,517)
P1584ENc

Figure 31 - Blocking 1

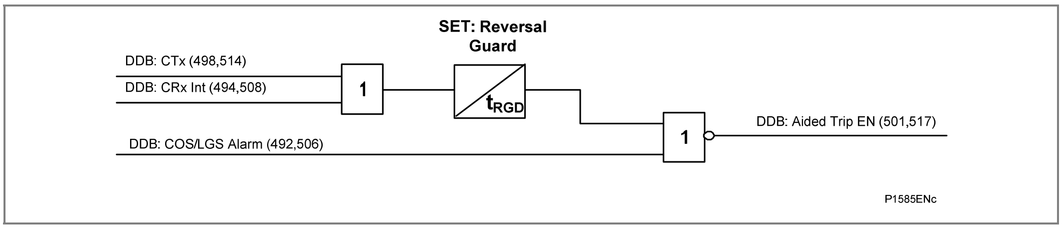

SET: Reversal Guard
DDB: CTx (498,514)
DDB: CRx Int (494,508)
1
t_{RGD}
DDB: COS/LGS Alarm (492,506)
1
DDB: Aided Trip EN (501,517)
P1585ENc

Figure 32 - Blocking 2

The relative merits of Blocking 1 and Blocking 2 are discussed in the Application Notes.

1.18.10 Aided DEF Ground Fault Scheme - Permissive Overreach

Figure 33 shows the element reaches, and Figure 34 the simplified scheme logic. The signaling channel is keyed from operation of the forward IN> DEF element of the relay. If the remote relay has also detected a forward fault, then it will operate with no additional delay upon receipt of this signal.

Send logic: IN> Forward pickup

Permissive trip logic: IN> Forward plus Channel Received

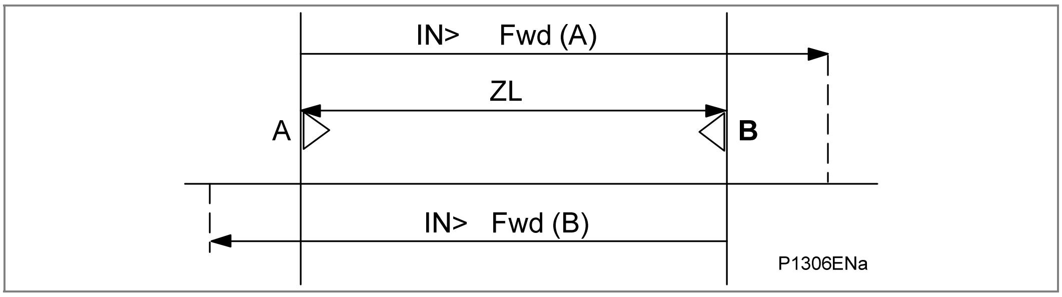

IN> Fwd (A)
ZL
A
B
IN> Fwd (B)
P1306ENa

Figure 33 - DEF permissive scheme

The scheme has the same features/requirements as the corresponding distance scheme and provides sensitive protection for high resistance earth faults.

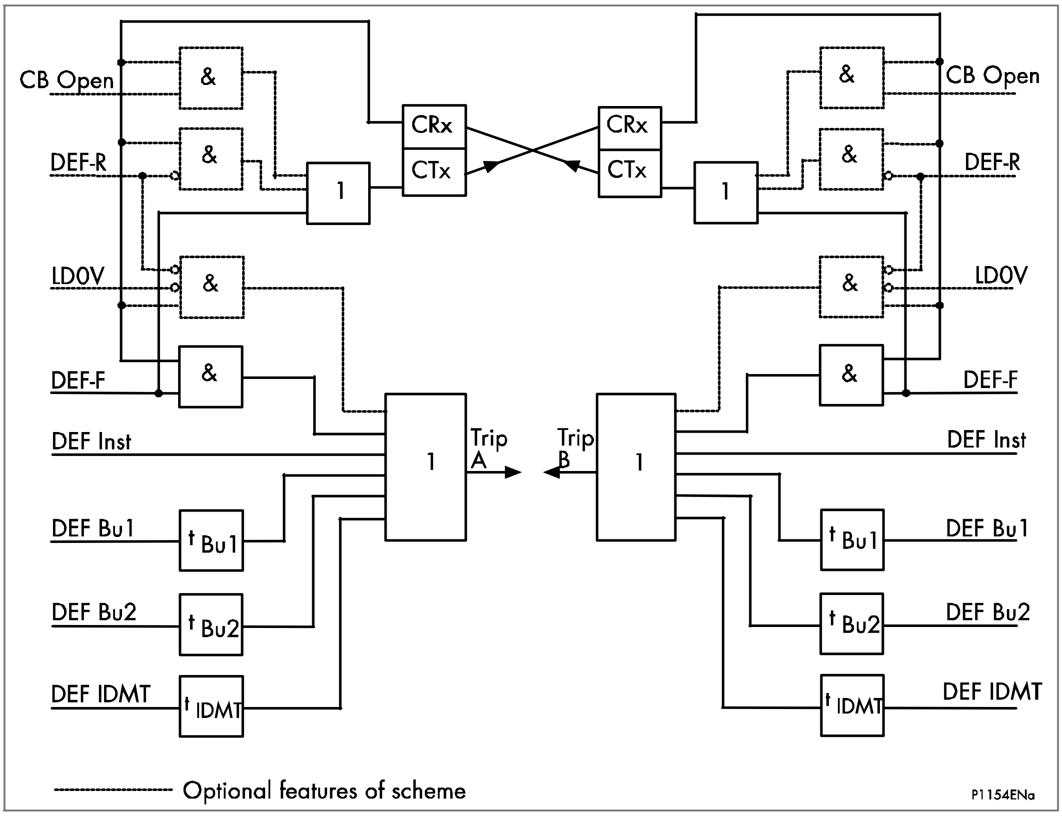

CB Open
DEF-R
LD0V
DEF-F
DEF Inst
DEF Bu1
DEF Bu2
DEF IDMT
&
1
CRx
CTx
Trip A
Trip B
t Bu1
t Bu2
t IDMT
Optional features of scheme
P1154ENa

Figure 34 - Aided DEF (ground) permissive scheme logic

1.18.11 Aided DEF Ground Fault Scheme - Blocking

Figure 35 shows the element reaches, and Figure 36 the simplified scheme logic. The signaling channel is keyed from operation of the reverse DEF element of the relay. If the remote relay forward IN> element has picked up, then it will operate after the set Time Delay if no block is received.

Send logic: DEF Reverse

Trip logic: IN> Forward, plus Channel NOT Received, with small set delay

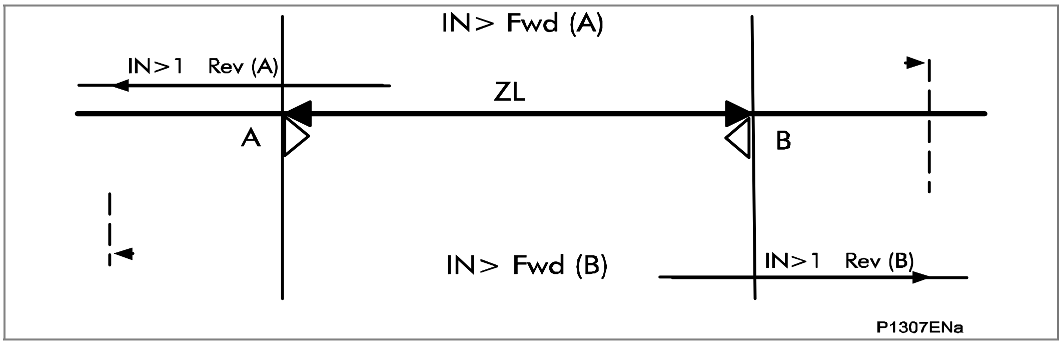

IN> Fwd (A)
IN>1 Rev (A)
ZL
A
B
IN> Fwd (B)
IN>1 Rev (B)
P1307ENa

Figure 35 - DEF blocking scheme

The scheme has the same features/requirements as the corresponding distance scheme and provides sensitive protection for high resistance earth faults.

Where "**t**" is shown in the diagram this signifies the time delay associated with an element. To allow time for a blocking signal to arrive, a short time delay on aided tripping must be used.

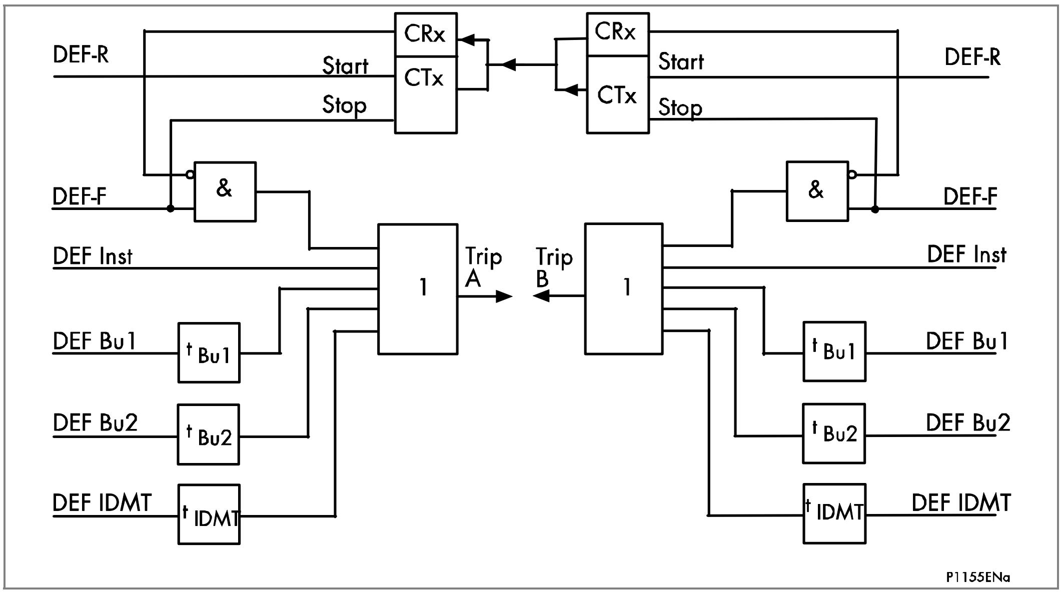


Figure 36 - Aided DEF (ground) blocking scheme logic

1.18.12 Delta Scheme POR - Permissive Overreach Transfer Trip

The channel for a directional comparison POR scheme is keyed by operation of the overreaching “**Delta Forward**” elements of the relay. If the remote relay has also detected a forward fault upon receipt of this signal, the relay will operate. Listed below are some of the main features/requirements for a permissive overreaching scheme:

- Permissive overreach schemes tend to be more secure than blocking schemes because forward directional decisions must be made at both ends of the line before tripping is allowed. Failure of the signaling channel will not result in unwanted tripping.
- If the infeed source at either end of the line is weak, the POR scheme must be supplemented with Weak Infeed logic.
- The scheme requires a duplex signaling channel to prevent possible relay mal-operation due to spurious keying of the signaling equipment. This is necessary due to the fact that the signaling channel is keyed for faults external to the protected line.
- Current reversal guard logic is used to prevent healthy line protection mal-operation for the high speed current reversals experienced in double circuit lines, caused by sequential opening of circuit breakers.
- If the signaling channel fails, Basic distance scheme tripping will be available.

This scheme is similar to that used in the LFDC relay, and is shown in Figure 37.

Send logic: Δ Fault Forward

Permissive trip logic: Δ Fault Forward plus Channel Received.

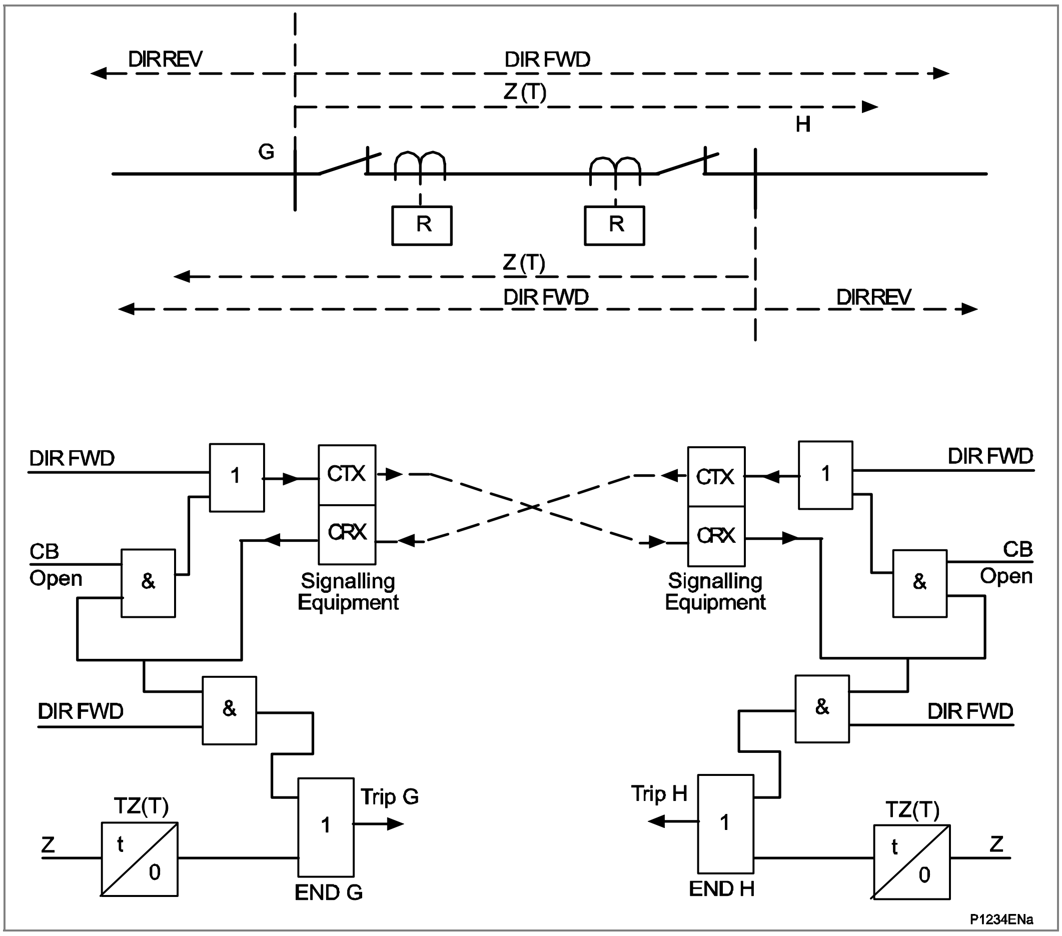

DIR REV
DIR FWD
Z (T)
H
G
R
R
Z (T)
DIR FWD
DIR REV
DIR FWD
1
CTX
CRX
Signalling Equipment
CB Open
&
DIR FWD
&
1
Trip G
END G
TZ(T)
Z
t
0
CTX
CRX
Signalling Equipment
1
DIR FWD
CB Open
&
&
DIR FWD
Trip H
1
END H
TZ(T)
t
0
Z
P1234ENa

Figure 37 - Delta directional comparison POR scheme

1.18.13 Delta Blocking Scheme

The signaling channel is keyed from operation of the "**Delta Reverse**" elements of the relay. If the remote relay has detected "**Delta Forward**", then it will operate after the trip delay if no block is received. Listed below are some of the main features/requirements for a permissive overreaching scheme:

- BLOCKING schemes require only a simplex signaling channel.
- The blocking signal is transmitted over a healthy line, and so there are no problems associated with power line carrier signaling equipment.
- Delta blocking schemes tend to be less secure than permissive schemes because failure of the signaling channel could result in an unwanted tripping later. Thus blocking schemes are best supervised by use of a "**Channel out of Service**" indication.
- Fast tripping will occur at a strong source line end, for faults along the protected line section, even if there is weak or zero infeed at the other end of the protected line.
- If a line terminal is open, fast tripping will still occur for faults along the whole of the protected line length.
- A current reversal guard timer is included in the signal send logic to prevent unwanted trips of the relay on the healthy circuit, during current reversal situations on a parallel circuit.

- To allow time for a blocking signal to arrive, a short time delay on aided tripping, “**Delta dly**”, must be used.

This scheme is similar to that used in the LFDC relay, and is shown in Figure 38.

Send logic: Δ Fault Reverse

Trip logic: Δ Fault Forward, plus Channel NOT Received, delayed by Tp.

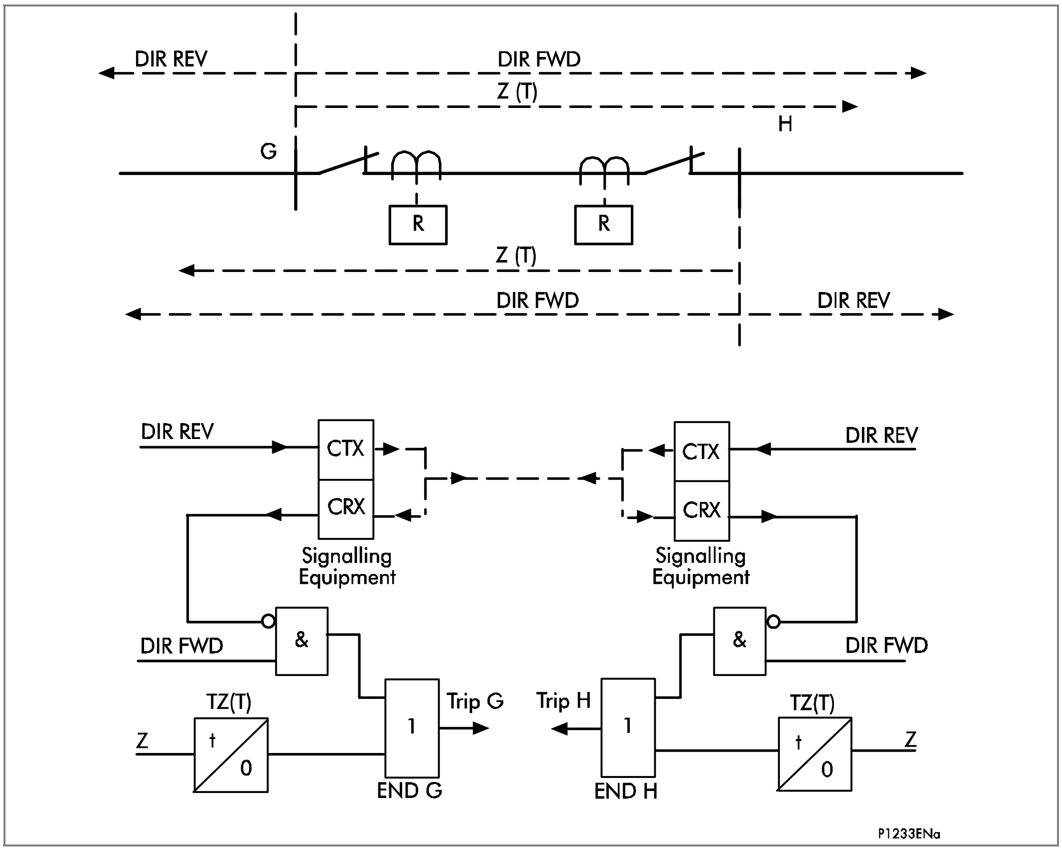

DIR REV
DIR FWD
Z (T)
H
G
R
R
Z (T)
DIR FWD
DIR REV
DIR REV
CTX
CRX
Signalling Equipment
CTX
CRX
DIR REV
Signalling Equipment
DIR FWD
&
&
DIR FWD
TZ(T)
Trip G
Trip H
TZ(T)
Z
t
0
1
1
t
0
Z
END G
END H
P1233ENa

Figure 38 - Delta directional comparison BLOCKING scheme

1.19 Zone 1 Extension and Loss of Load Schemes

The MiCOM P443/P446 offers additional non-channel distance schemes, notably Zone 1 extension, and loss of load.

1.19.1 Zone 1 Extension Scheme

Auto-reclosure is widely used on radial overhead line circuits to re-establish supply following a transient fault. A Zone 1 extension scheme may therefore be applied to a radial overhead feeder to provide high speed protection for transient faults along the whole of the protected line. Figure 39 shows the alternative reach selections for zone 1: Z1 or the extended reach Z1X.

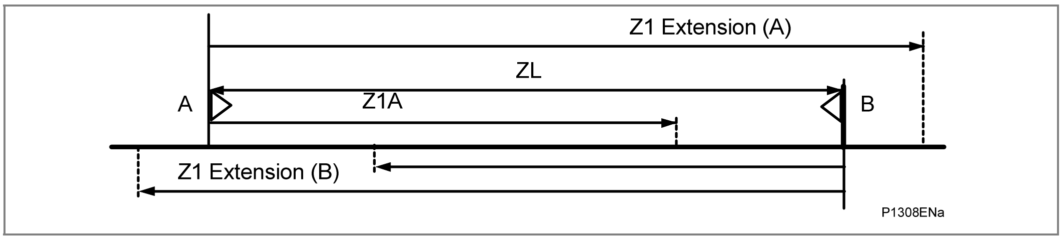

Z1 Extension (A)
ZL
A
Z1A
B
Z1 Extension (B)
P1308ENa

Figure 39 - Zone 1 extension scheme

In this scheme, Zone 1X is enabled and set to overreach the protected line. A fault on the line, including one in the end 20% not covered by zone 1, will now result in instantaneous tripping followed by auto-reclosure. Zone 1X has resistive reaches and residual compensation similar to Zone 1. The auto-recloser in the relay is used to inhibit tripping from zone 1X such that upon reclosure the relay will operate with Basic scheme logic only, to co-ordinate with downstream protection for permanent faults. Thus, transient faults on the line will be cleared instantaneously, which will reduce the probability of a transient fault becoming permanent. The scheme can, however, operate for some faults on an adjacent line, although this will be followed by auto-reclosure with correct protection discrimination. Increased circuit breaker operations would occur, together with transient loss of supply to a substation.

The time delays associated with extended zone Z1X are shown in the table below:

Scenario	Z1X Time Delay
First fault trip	= tZ1
Fault trip for persistent fault on auto-reclose	= tZ2

Table 4 - Time delays associated with extended zone Z1X

The Zone 1X reach is set as a percentage of the Zone 1 reach, i.e. as a reach multiplier.

Note *The Zone 1 extension scheme can be “**Disabled**”, permanently “**Enabled**” or just brought into service when the distance communication channel fails and the aided scheme would be inoperative. A selection of which out of the two channels available in The* MiCOM *P443/P446 is monitored, is provided, with selections from Channel 1 and Channel 2 in any combination. The Logic Diagram is attached as Figure 40:*

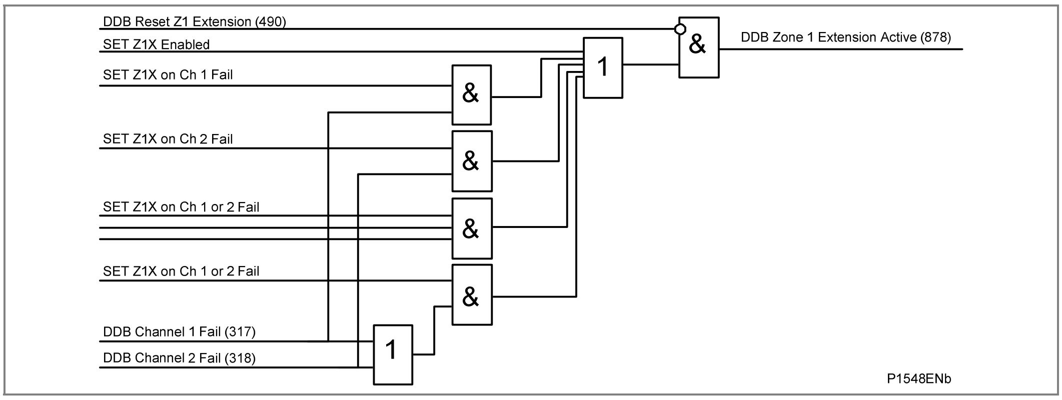

DDB Reset Z1 Extension (490)
SET Z1X Enabled
SET Z1X on Ch 1 Fail
SET Z1X on Ch 2 Fail
SET Z1X on Ch 1 or 2 Fail
SET Z1X on Ch 1 or 2 Fail
DDB Channel 1 Fail (317)
DDB Channel 2 Fail (318)
&
&
&
&
&
1
1
DDB Zone 1 Extension Active (878)
P1548ENb

Figure 40 - Zone 1 extension

1.19.2 Loss of Load (LoL) Accelerated Tripping

The loss of load accelerated trip logic is shown in abbreviated form in Figure 41. The loss of load logic provides fast fault clearance for faults over the whole of a double end fed protected circuit for all types of fault, except three phase. The scheme has the advantage of not requiring a signaling channel. Alternatively, the logic can be chosen to be enabled when the channel associated with an aided scheme has failed. This failure is detected by permissive scheme unblocking logic, or a Channel Out of Service (COS) opto input. A selection of which out of the two channels available in The MiCOM P443/P446 is monitored, is provided, with selections from Channel 1 and Channel 2 in any combination.

Any fault located within the reach of Zone 1 will result in fast tripping of the local circuit breaker. For an end zone fault with remote infeed, the remote breaker will be tripped in Zone 1 by the remote relay and the local relay can recognize this by detecting the loss of load current in the healthy phases. This, coupled with operation of a Zone 2 comparator causes tripping of the local circuit breaker.

Before an accelerated trip can occur, load current must have been detected prior to the fault. The loss of load current opens a window during which time a trip will occur if a Zone 2 comparator operates. A typical setting for this window is 40ms as shown in 0, although this can be altered in the menu "**LoL Window**" cell. The accelerated trip is delayed by 18ms to prevent initiation of a loss of load trip due to circuit breaker pole discrepancy occurring for clearance of an external fault. The local fault clearance time can be deduced as follows:

t = Z1d + 2CB + LDr + 18ms

Where:

Z1d = Maximum downstream zone 1 trip time

CB = Breaker operating time

LDr = Upstream level detector (LoL: I<) reset time

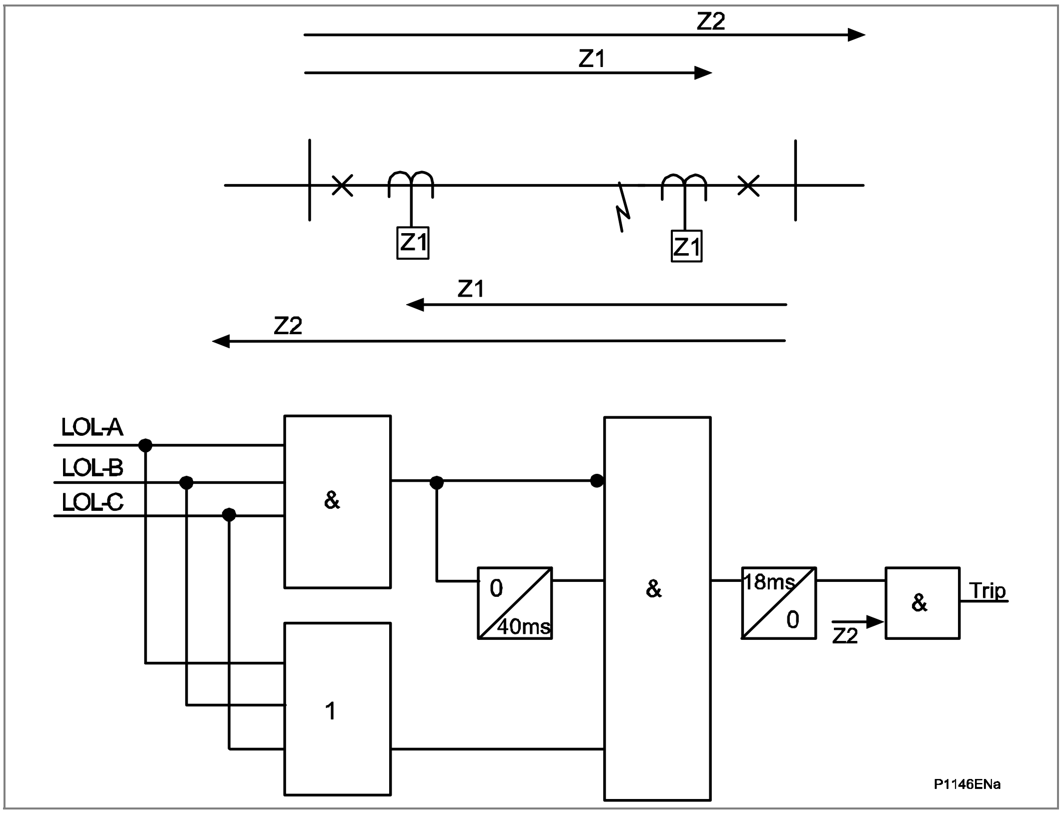


Figure 41 - Loss of load accelerated trip scheme

For circuits with load tapped off the protected line, care must be taken in setting the loss of load feature to ensure that the I< level detector setting is above the tapped load current. When selected, the loss of load feature operates in conjunction with the main distance scheme that is selected. In this way it provides high speed clearance for end zone faults when the Basic scheme is selected or, with permissive signal aided tripping schemes, it provides high speed back-up clearance for end zone faults if the channel fails.

Note	*Loss of load tripping is only available where 3 pole tripping is used. The detailed Logic Diagram follows in Figure 42.*

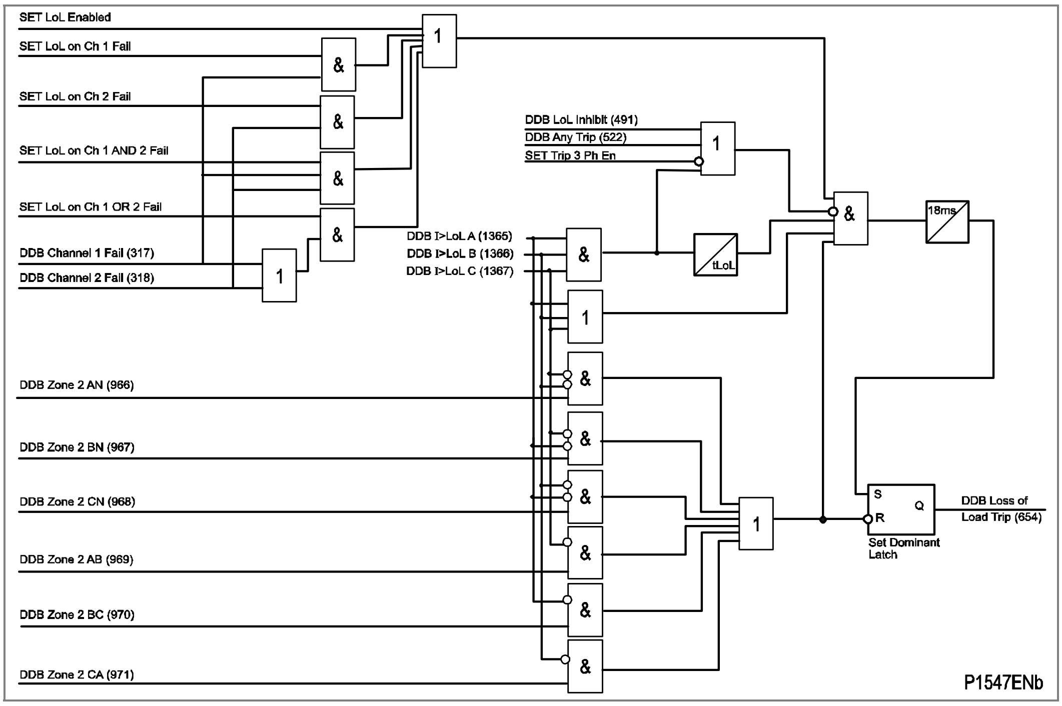

SET LoL Enabled
SET LoL on Ch 1 Fail
SET LoL on Ch 2 Fail
SET LoL on Ch 1 AND 2 Fail
SET LoL on Ch 1 OR 2 Fail
DDB Channel 1 Fail (317)
DDB Channel 2 Fail (318)
DDB LoL Inhibit (491)
DDB Any Trip (522)
SET Trip 3 Ph En
DDB I>LoL A (1365)
DDB I>LoL B (1366)
DDB I>LoL C (1367)
tLoL
18ms
DDB Zone 2 AN (966)
DDB Zone 2 BN (967)
DDB Zone 2 CN (968)
DDB Zone 2 AB (969)
DDB Zone 2 BC (970)
DDB Zone 2 CA (971)
&
1
S
R
Q
Set Dominant Latch
DDB Loss of Load Trip (654)
P1547ENb

Figure 42 - Loss of load

1.20 InterMiCOM

1.20.1 Protection Signaling

To achieve fast fault clearance and correct discrimination for faults anywhere in a high voltage power network, it is necessary to signal between the points at which protection relays are connected. The following two distinct types of protection signaling can be identified.

Unit protection schemes

> In these schemes the signaling channel is used to convey analog data representative of the power system between relays. Typically current magnitude and/or phase information is communicated between line ends to enable a unit protection scheme to be implemented. These unit protection schemes are not covered by InterMiCOM or InterMiCOM^{64}. Instead, the MiCOM P52x and P54x range of current differential and phase comparison relays are available for unit applications.

Teleprotection - channel aided schemes

> In channel-aided schemes the signaling channel is used to convey simple ON/OFF commands from a local protection device to a remote device to provide some additional information to be used in the protection scheme operation. The commands can be used to accelerate in-zone fault clearance or to prevent out-of-zone tripping, or both.

The InterMiCOM application is an effective replacement to the traditional hardwired logic and communication schemes used by protection relays for such teleprotection signaling.

The MiCOM Px4x series products have a grouping of internal digital signals known as the digital data bus, DDB, that are used to implement the protection scheme logic. A number of these DDB signals are reserved as inputs and outputs for the InterMiCOM application. These are mapped using the programmable scheme logic (PSL) support tool. The InterMiCOM application provides a means of transferring the status of these mapped DDB signals between the protection relays using dedicated full-duplex communications channels.

1.20.2 InterMiCOM Variants

There are two different types of integrated InterMiCOM teleprotection available in the MiCOM P443/P446 relays:

- An optical fiber implementation, InterMiCOM^{64} - designed, primarily, to work over fiber optic and multiplexed digital communications channels with data rates of 56/64kbit/s. A total of 16 InterMiCOM^{64} commands (16 inputs and 16 outputs) are available in the P443/P446. These are arranged as two groups of 8 bits each, and are referred to as Channel 1 and Channel 2. Three InterMiCOM^{64} scheme arrangements are possible:
- Two-terminal with a single communications link
- Two-terminal with a dual redundant communications link (sometimes referred to as '**hot standby**')
- Three terminal (or triangulated) scheme
- An electrical implementation of InterMiCOM, realised over an EIA(RS)232 medium typically for MODEM applications and referred to as MODEM InterMiCOM for ease of differentiation with InterMiCOM^{64}. MODEM InterMiCOM supports two-terminal applications with a single communications channel. Eight MODEM InterMiCOM commands can be transmitted between the line ends.

Provided the correct hardware options have been specified, it is possible to configure the P443/P446 to operate using either InterMiCOM^{64} or MODEM InterMiCOM, or both. The selection is made under the CONFIGURATION column of the menu software.

1.20.3 InterMiCOM Features

The different requirements of applications that use teleprotection signaling for direct acting, permissive, or blocking schemes are all catered for by InterMiCOM.

Communications are supervised and alarms and signal defaults can be defined to give controlled actions in the event of communications signals being distorted or unavailable.

Communications statistics and loopback features are available to help with commissioning and testing purposes.

Both, InterMiCOM^{64} and MODEM InterMiCOM teleprotection provide the ideal means to configure the schemes in the MiCOM P443/P446 relay. The selection between the two will generally depend on communications media availability, system configuration, distances, cost issues and utility practice.

1.20.4 Definition of Teleprotection Commands

Three generic types of teleprotection command can be defined. These are Intertripping, Permissive signaling, and Blocking. All teleprotection signals are initiated in a transmitting relay but, according to the application, the receiving relay may condition the signal according to the scheme requirements:

Intertripping	In intertripping (also called direct or transfer tripping) applications, the command is not supervised at the receiving end by any protection relay and its receipt causes direct circuit breaker operation. Since no checking of the received signal by another protection element is performed, it is essential that any noise on the signaling channel is not interpreted as being a valid signal when the command isn't being transmitted. For an intertripping scheme, therefore, the primary requirement of the signaling channel is security.
Permissive	In permissive applications, tripping is only permitted when the command coincides with a protection operation at the receiving end. Since the receiver applies a second independent check before tripping, the signaling channel for a permissive scheme does not have to be quite as secure as for an intertripping scheme, but it may need to be faster.
Blocking	In blocking applications, tripping occurs when a protection element picks up in a receiving relay whilst no signal is received from a remote relay. In such schemes, when the command is received, the protection element is blocked even if a protection element picks up. Since the signal is used to prevent tripping, it is a requirement that the signal should be available whenever possible, and that it should be received as quickly as possible. The requirements of a blocking channel are, therefore, to be fast and to be dependable. Figure 43 shows the requirements for the three channel types.

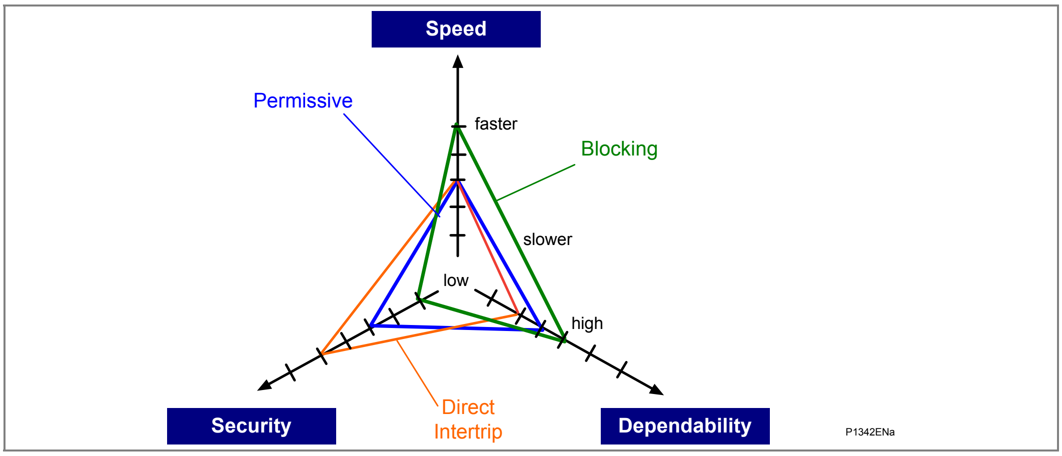


Figure 43 - Pictorial comparison of operating modes

This diagram shows that a blocking signal should be fast and dependable; a direct intertrip signal should be very secure; and a permissive signal is an intermediate compromise of speed, security and dependability.

In MODEM InterMiCOM applications, selected signaling bits within each message can be conditioned to provide optimal characteristics for each of the three teleprotection command types.

In InterMiCOM^{64} applications, the framing and error checking of a single command message is sufficient to meet the security of a permissive application, while the speed is sufficiently fast to meet the needs of a blocking scheme. Accordingly in InterMiCOM^{64} applications, there is no differentiation between blocking commands or permissive commands, so that only signals being used for direct intertripping with higher security requirements need to be differentiated from those in permissive (or blocking) schemes.

1.21 MODEM InterMiCOM, EIA(RS)232 InterMiCOM or Copper InterMiCOM

1.21.1 Communications Media

MODEM InterMiCOM is capable of transferring up to eight commands over one communication channel. Due to recent expansions in communication networks, most signaling channels are now digital schemes utilizing multiplexed communications links and for this reason, MODEM InterMiCOM provides a standard EIA(RS)232 output using digital signaling techniques. This digital signal can then be converted using suitable devices to a range of different communications media as required. The EIA(RS)232 output may alternatively be connected to MODEMs for use over analogue links.

Regardless of whether analogue or digital systems are being used, all the requirements of teleprotection commands are described by an international standard, IEC60834-1:1999, and MODEM InterMiCOM is compliant with the essential requirements of this standard. This standard describes the speed requirements of the commands as well as the security (defined in terms of probability of unwanted commands being received) and dependability (defined in terms of the probability of missing commands).

Additional security can now be achieved by using Cyber Security settings. This is now an option for products which use Software Release D0 and later.

1.21.2 General Features and Implementation

InterMiCOM provides eight commands over a single communications link, with the mode of operation of each command being individually selectable within the **IM# Cmd Type** cell. **Blocking** mode provides the fastest signaling speed (available on commands 1 - 4), **Direct Intertrip** mode provides the most secure signaling (available on commands 1 - 8) and **Permissive** mode provides secure, dependable signaling (available on commands 5 - 8). Each command can also be disabled so that it has no effect in the logic of the relay.

Since many applications involve commands being sent over a multiplexed communications channel, it is necessary to ensure that only data from the correct relay is used. The relays in the scheme must be programmed with a unique pair of addresses that correspond with each other in the **Source Address** and **Receive Address** cells. For example, at the local end relay, if the **Source Address** is set to 1, the **Receive Address** at the remote end relay must also be set to 1. Similarly, if the remote end relay has a **Source Address** set to 2, the **Receive Address** at the local end must also be set to 2. The two pairs of addresses should be set to be different in any scheme to avoid the possibility of incorrect operation during inadvertent loopback connections, and any schemes sharing the same communications services should be set to have different address pairs in order to avoid any problems caused by inadvertent cross-channel connections.

Noise on the communications should not be interpreted as valid commands by the relay. For this reason, InterMiCOM uses a combination of unique pair addressing described above, basic signal format checking and an 8-bit Cyclic Redundancy Check (CRC) according to the security requirements of the commands. The CRC calculation is performed at both the sending and receiving end relays for each message and both must match in order to assure the security of the **Direct Intertrip** commands.

An alarm is provided if noise on the communications channel becomes excessive.

During periods of excessive noise, it is possible that the synchronization of the message structure will be lost and accurate decoding of the messages may not be possible. Predictable operation of InterMiCOM is assured during such noisy periods by means of the **IM# FallBackMode** cell. The status of the last received valid command can be maintained until a new valid message is received by setting the **IM# FallBackMode** cell to **Latched**. Alternatively, a known fallback state can be assigned to the command by setting the **IM# FallBackMode** cell to **Default**. In this latter case, the time period between communication disruption and the default state being restored will need to be set in the **IM# FrameSynTim** cell and the default value will need to be set in **IM# DefaultValue** cell. Upon subsequent receipt of a valid message, all the timer periods will be reset and the new valid command states will be used.

If there is a total communications failure, the relay will use the fallback (failsafe) strategy as described above. Total failure of the channel is considered when no message data is received for four power system cycles or if there is a loss of the DCD line.

1.21.3 EIA(RS)232 Physical Connections

MODEM InterMiCOM on the Px4x relays is implemented using a 9-pin D-type female connector (labeled SK5) located at the bottom of the 2nd Rear communication board. This connector on the Px40 relay is wired in DTE (Data Terminating Equipment) mode, as shown in the following table.

Pin	Acronym	InterMiCOM Usage
1	DCD	Data Carrier Detect is only used when connecting to modems otherwise this should be tied high by connecting to terminal 4
2	RxD	Receive Data
3	TxD	Transmit Data
4	DTR	Data Terminal Ready is permanently tied high by the hardware since InterMiCOM requires a permanently open communication channel
5	GND	Signal Ground
6	Not used	-
7	RTS	Ready To Send is permanently tied high by the hardware since InterMiCOM requires a permanently open communication channel
8	Not used	-
9	Not used	-

Table 5 - SK5 9-pin 'D' type female connector wiring pins

Dependant upon whether a direct or modem connection between the two relays in the scheme is being used, the required pin connections are described as follows:

1.21.4 Direct Connection

EIA(RS)232 is only suitable for short transmission distances due to the signaling levels used and the connection shown below is limited to less than 15m. This limit may be overcome by introducing suitable signal converters as described in the following sections:

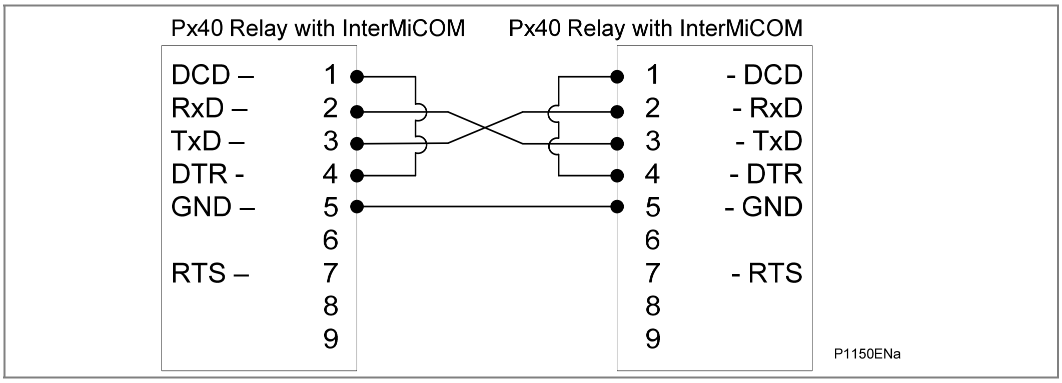


Figure 44 - Direct connection within the local substation

The connection configuration shown in 0 should also be used when connecting to equipment that does not implement control the DCD line.

1.21.5 EIA(RS)232 Modem Connection

To achieve longer distance communication, modems may be used, in which the case the following connections should be made.

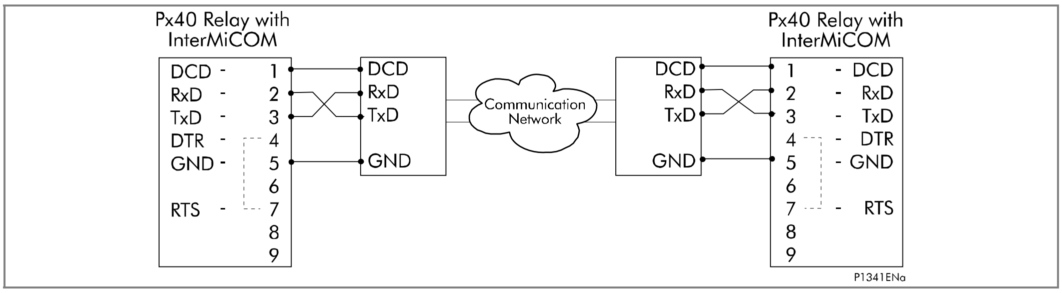

Px40 Relay with InterMiCOM
DCD - 1
RxD - 2
TxD - 3
DTR - 4
GND - 5
6
RTS - 7
8
9
DCD
RxD
TxD
GND
Communication Network
DCD
RxD
TxD
GND
Px40 Relay with InterMiCOM
1 - DCD
2 - RxD
3 - TxD
4 - DTR
5 - GND
6
7 - RTS
8
9
P1341ENa

Figure 45 - InterMiCOM teleprotection via a MODEM link

This type of connection should be used when connecting to multiplexers which provide an EIA(RS)232 channel with the ability to control the DCD line. With this type of connection it should be noted that the maximum distance between the Px40 relay and the modem should not exceed 15m, and that a baud rate suitable for the communications path used should be selected.

1.21.6 RS422 Connection

An RS232 to RS422 converter such as Schneider Electric CK212 may be employed to enable MODEM InterMiCOM to be applied if 4-wire pilots are available for signaling as shown in the example below.

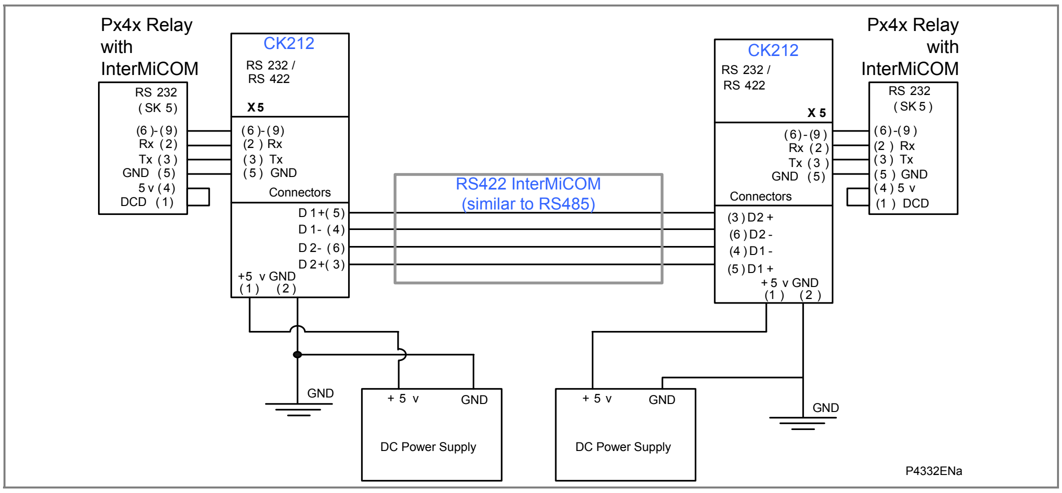

Px4x Relay with InterMiCOM
RS 232 (SK 5)
(6)-(9)
Rx (2)
Tx (3)
GND (5)
5 v (4)
DCD (1)
CK212
RS 232 / RS 422
X5
(6)-(9)
(2) Rx
(3) Tx
(5) GND
Connectors
D1+(5)
D1-(4)
D2-(6)
D2+(3)
+5 v GND
(1) (2)
RS422 InterMiCOM (similar to RS485)
CK212
RS 232 / RS 422
X 5
(6)-(9)
Rx (2)
Tx (3)
GND (5)
Connectors
(3) D2 +
(6) D2 -
(4) D1 -
(5) D1 +
+5 v GND
(1) (2)
Px4x Relay with InterMiCOM
RS 232 (SK5)
(6)-(9)
(2) Rx
(3) Tx
(5) GND
(4) 5 v
(1) DCD
GND
+ 5 v
GND
DC Power Supply
+ 5 v
GND
DC Power Supply
GND
P4332ENa

Figure 46 - MODEM InterMiCOM teleprotection via a RS422 protocol

Using an appropriate converter, pilots of up to 1.2km in length can be used, depending on the converter performance.

In this case, the maximum distance between the Px40 relay and the converter should not exceed 15m.

1.21.7 Fiber Optic Connection

Although InterMiCOM^{64} is the recommended variant of InterMiCOM for use with optical fiber connections, MODEM InterMiCOM may also be applied over optical fibers using EIA(RS)232 to fiber optic converters. In this the case the following connections should be made:

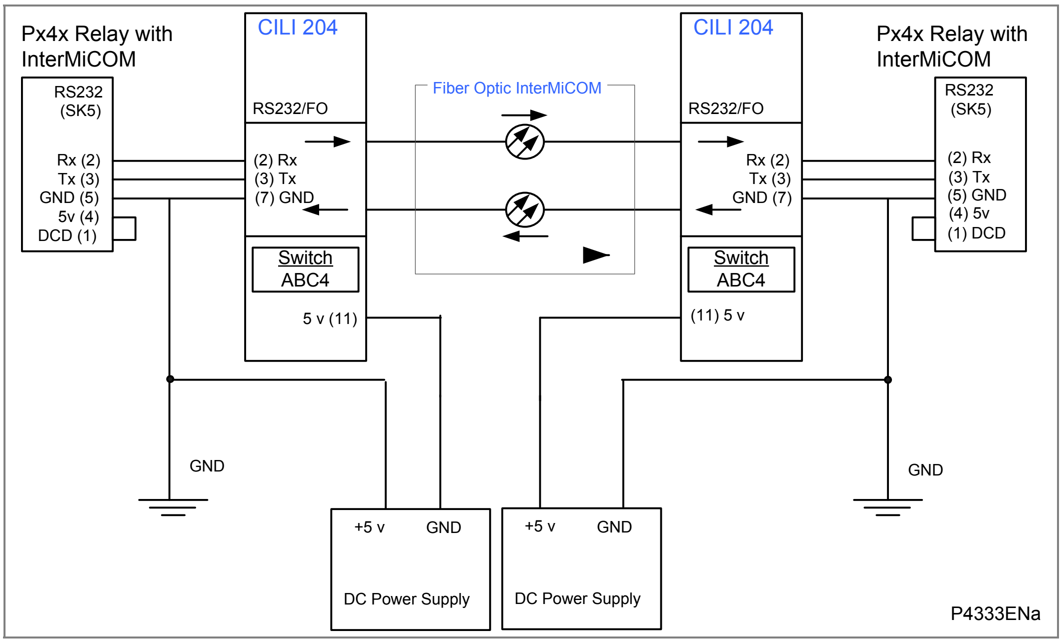

Px4x Relay with InterMiCOM
RS232 (SK5)
Rx (2)
Tx (3)
GND (5)
5v (4)
DCD (1)
CILI 204
RS232/FO
(2) Rx
(3) Tx
(7) GND
Switch ABC4
5 v (11)
Fiber Optic InterMiCOM
CILI 204
RS232/FO
Rx (2)
Tx (3)
GND (7)
Switch ABC4
(11) 5 v
Px4x Relay with InterMiCOM
RS232 (SK5)
(2) Rx
(3) Tx
(5) GND
(4) 5v
(1) DCD
GND
+5 v
GND
DC Power Supply
+5 v
GND
DC Power Supply
GND
P4333ENa

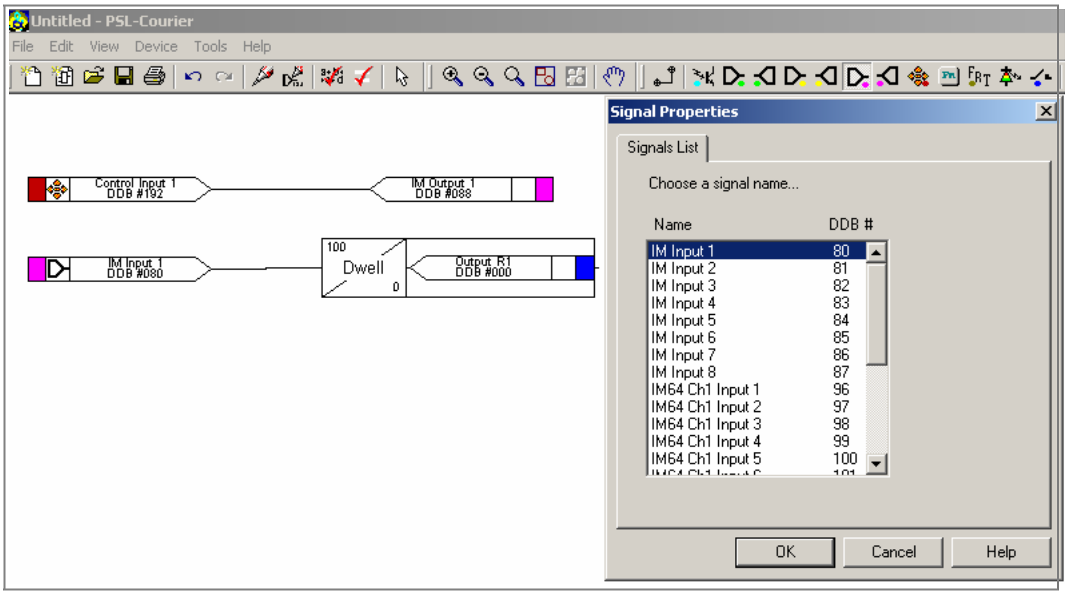
Figure 47 - MODEM InterMiCOM teleprotection via fiber optic

The overall fiber length that can be achieved depends on the converter performance.

In this case, the maximum distance between the Px40 relay and the converter should not exceed 15m.

1.21.8 InterMiCOM Functional Assignment

The settings to control the mode of the intertrip signals are made using the relay's menu software. In addition to this, it is necessary to assign InterMiCOM input and output signals in the relay Programmable Scheme Logic (PSL) editor. Two icons are provided on the PSL editor of MiCOM S1 (S1 Studio) for **Integral tripping In** and **Integral tripping out** which can be used to assign the eight intertripping commands. The example shown in 0 shows a **Control Input_1** connected to the **Intertrip O/P1** signal which would then be transmitted to the remote end. At the remote end, the **Intertrip I/P1** signal would then be assigned within the PSL. In this example, we can see that when intertrip signal 1 is received from the remote relay, the local end relay would operate an output contact, R1.


Untitled - PSL-Courier
File
Edit
View
Device
Tools
Help
Control Input 1
DDB #192
IM Output 1
DDB #088
IM Input 1
DDB #080
100
Dwell
0
Output R1
DDB #000
Signal Properties
Signals List
OK
Cancel
Help

Choose a signal name...

Name	DDB #
IM Input 1	80
IM Input 2	81
IM Input 3	82
IM Input 4	83
IM Input 5	84
IM Input 6	85
IM Input 7	86
IM Input 8	87
IM64 Ch1 Input 1	96
IM64 Ch1 Input 2	97
IM64 Ch1 Input 3	98
IM64 Ch1 Input 4	99
IM64 Ch1 Input 5	100

Figure 48 - Example assignment of signals within the PSL

It should be noted that when an InterMiCOM signal is sent from the local relay, only the remote end relay will react to this command. The local end relay will only react to InterMiCOM commands initiated at the remote end and received locally, and vice-versa. InterMiCOM can, therefore, be described as a duplex teleprotection system.

1.21.9 InterMiCOM Statistics and Diagnostics

MODEM InterMiCOM channel statistics and diagnostics are available via the menu software. These can be hidden by setting the **Ch Statistics** cell or **Ch Diagnostics** cell, or both, to **Invisible**. All channel statistics are reset when the relay is powered up, or by user selection using the **Reset Statistics** cell.

1.22 InterMiCOM^{64} (“Fiber InterMiCOM”)

1.22.1 General Features and Implementation

InterMiCOM^{64} is an optional feature, offering very fast fault clearance in distance aided schemes with a typical end-end delay of 5ms for Permissive/Blocking signals and around 6ms for Intertripping (adding the channel time delay where multiplexers are used).

InterMiCOM^{64} provides a direct fiber output from the relay’s co-processor board that can be connected either directly to the protection at the remote end(s) or via appropriate interfaces and multiplexed communications channels, similar to MiCOM P52x and P54x line differential relays. InterMiCOM^{64} can use two channels for communication. The second channel is used in dual redundant two-terminal scheme or three-terminal scheme configurations. (Sometimes such schemes are termed “**hot standby**” and “**triangulated**” schemes, respectively).

InterMiCOM^{64} is designed, primarily, to work over fiber optic and multiplexed digital communications channels. A total of sixteen InterMiCOM^{64} commands (16 inputs and 16 outputs) are available in the MiCOM P443/P446. These are arranged as two groups of 8 bits each, and are referenced as Channel 1 and Channel 2.

Note *InterMiCOM^{64} Channel 1 and 2 references are not the same as references to communications Channels 1 and 2 and this can cause some confusion.*

InterMiCOM^{64} communications can run using two different user settable Baud rates: 56 and 64kbits/s, for ease of interfacing with standard public and private telecommunication networks.

InterMiCOM^{64} also supports the IEEE C37.94 standard for direct optical fiber connection to appropriately equipped multiplexers. In this case the data rate is matched to one of the Nx64 channels supported by the multiplexer.

1.22.2 Configuring InterMiCOM^{64}

InterMiCOM^{64} provides two groups of eight InterMiCOM^{64} commands. These groups of InterMiCOM^{64} commands are referenced as Channel 1 and Channel 2. The mapping of the InterMiCOM^{64} command signals is performed using the programmable scheme logic (PSL) editor (which is part of the MiCOM S1/S1 Studio support tool) in a manner similar to that described in section 1.21.8.

In addition to mapping the commands with the PSL editor, it is also necessary to configure the InterMiCOM^{64} communications scheme. This configuration is made using the settings found in the PROT COMMS/IM^{64} column of the menu software. These settings are described in detail in the settings (ST) section of this manual, but in order to facilitate understanding of InterMiCOM^{64} operation, they are also presented in the following sections.

The MiCOM P443/P446 can be equipped with either one or two fiber communications ports to support InterMiCOM^{64}. For the purposes of setting, labeling, etc., these communications ports are referenced as protection communications Channels 1 and 2. Although there is some association of the InterMiCOM^{64} signal groupings referenced Channels 1 and 2, with communications Channels 1 and 2, they have subtly different meanings and care needs to be taken to avoid confusion.

1.22.2.1 InterMiCOM^{64} Scheme Setup - Application

Three InterMiCOM^{64} scheme arrangements are possible:

- Two-terminal with a single communications link

- Two-terminal with a dual redundant communications link (sometimes referred to as '**hot standby**'
- Three terminal (or triangulated) scheme

The selection is made using the Scheme Setup setting.

In the two-terminal configurations, the 8 InterMiCOM^{64} commands of both channel 1 and channel 2 (i.e. all 16 commands) can be freely assigned within the scheme logic of the two relays. So long as a communications link between the two terminals is functioning, all 16 commands are usable. The advantage of a dual redundant scheme is the fact that scheme integrity can be maintained in the event of a failure of one of the communications links.

The triangulated scheme is designed such that the InterMiCOM^{64} communications can self-heal in the event of a failure of a communication link between any two terminals. It achieves this by routing the 8 InterMiCOM^{64} commands on Channel 1 for use by the relay connected to communications channel 1 (remote 1), and the 8 InterMiCOM^{64} commands on Channel 2 for use by the relay connected to communications channel 2 (remote 2). In the event of a failure of communications between say the local relay and remote 1, remote 2 will pass on the 8 InterMiCOM^{64} commands intended from local to remote1 using the second communications channel.

The recommended InterMiCOM^{64} connection for a three ended application is shown in Figure 49.

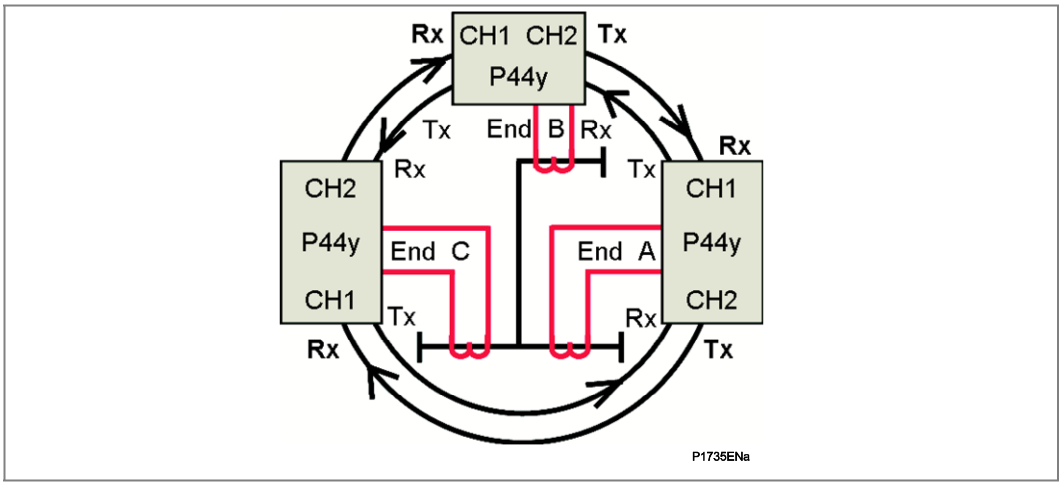


Figure 49 - Triangulated InterMiCOM^{64} application

It should be noted that in the case when one leg of the communication triangle fails, for example, channel A-C becomes unavailable, the InterMiCOM^{64} will continue to provide the full teleprotection scheme between all three ends in a degraded chain topology because of the way the 8 Channel 2 InterMiCOM^{64} commands are passed on via the scheme logic. In this degraded '**Chain**' topology, relays A and C will receive and transmit teleprotection commands via relay B. The retransmitting done by relay B (A-B-C and C-B-A) provides the self-healing for the lost links A-C and C-A).

This Chain topology may be employed as a means to save cost in implementing a three-terminal scheme, since two legs may be cheaper to install than full triangulation, or if a suitable communication link is not available between two of the line ends. It should be noted, however, that the operating speed of teleprotection commands will increase by approximately 7ms (plus communications channel signaling delay) when retransmitted in Chain topology, due to the extended path length.

1.22.2.2 InterMiCOM^{64} Protection Communications Address

The InterMiCOM^{64} communication messages include an address field to ensure correct scheme connection. There are twenty one address group selections available. These addresses are provided to ensure that commands are communicated only between the particular relays in the scheme. The address patterns are carefully designed to provide maximum security for the application, and within the ranges given, they are freely assignable.

The Universal Address can be useful during testing, but in deployment it should be avoided to prevent the possibility of incorrect operation during inadvertent loopback connections. In addition, and any schemes sharing the same communications services should be set to have different address patterns to avoid any problems caused by inadvertent cross-channel connection.

The groups of addresses available when a two-terminal or dual redundant InterMiCOM^{64} scheme is selected are as follows:

	Relay A	Relay B
Universal Address	0-0	0-0
Address Group 1	1-A	1-B
Address Group 2	2-A	2-B
Address Group 3	3-A	3-B
Address Group 4	4-A	4-B
Address Group 5	5-A	5-B
Address Group 6	6-A	6-B
Address Group 7	7-A	7-B
Address Group 8	8-A	8-B
Address Group 9	9-A	9-B
Address Group 10	10-A	10-B
Address Group 11	11-A	11-B
Address Group 12	12-A	12-B
Address Group 13	13-A	13-B
Address Group 14	14-A	14-B
Address Group 15	15-A	15-B
Address Group 16	16-A	16-B
Address Group 17	17-A	17-B
Address Group 18	18-A	18-B
Address Group 19	19-A	19-B
Address Group 20	20-A	20-B

Table 6 - Address groups for a two-terminal or dual redundant scheme

For two relays to communicate with one another, their addresses need to be in the same address group. One relay should be assigned with address A and the other with address B. For example, if the group 1 address is used, one relay should be given the address 1-A, and the other relay should be given the address 1-B. The relay with address 1-A will only accept messages with the 1-A address and will send out messages carrying address 1-B. The relay assigned with address 1-B will only accept messages with address 1-B and will send out messages carrying address 1-A.

The groups of addresses available when a three-terminal InterMiCOM^{64} scheme is selected are as follows:

	Relay A	Relay B	Relay C
Address Group 1	1-A	1-B	1-C

	Relay A	Relay B	Relay C
Address Group 2	2-A	2-B	2-C
Address Group 3	3-A	3-B	3-C
Address Group 4	4-A	4-B	4-C
Address Group 5	5-A	5-B	5-C
Address Group 6	6-A	6-B	6-C
Address Group 7	7-A	7-B	7-C
Address Group 8	8-A	8-B	8-C
Address Group 9	9-A	9-B	9-C
Address Group 10	10-A	10-B	10-C
Address Group 11	11-A	11-B	11-C
Address Group 12	12-A	12-B	12-C
Address Group 13	13-A	13-B	13-C
Address Group 14	14-A	14-B	14-C
Address Group 15	15-A	15-B	15-C
Address Group 16	16-A	16-B	16-C
Address Group 17	17-A	17-B	17-C
Address Group 18	18-A	18-B	18-C
Address Group 19	19-A	19-B	19-C
Address Group 20	20-A	20-B	20-C

Table 7 - Address groups for a three-terminal scheme

For three relays to work together as a protection system, their addresses must be in the same group and they should be assigned separately with addresses A, B and C. They must also have a fixed connection configuration, as shown in 0, in which channel 1 of one relay is connected to channel 2 of another relay.

For example, if the group 1 address is used, addresses 1-A, 1-B and 1-C should be assigned to relays A, B and C respectively. Relay A will only accept messages with address 1-A and will send messages carrying addresses 1-B and 1-C to channel 1 and channel 2 respectively. Relay B will only accept messages with address 1-B and will send messages carrying addresses 1-C and 1-A to channel 1 and to channel 2 respectively. Similarly relay C will only accept messages with address 1-C and will send messages carrying addresses 1-A and 1-B to channel 1 and to channel 2 respectively.

1.22.2.3 InterMiCOM^{64} communications mode setup

The Communications Mode setup configures the optical fiber ports either as “**standard**”, or as “**IEEE C37.94**”. If connection is to be made to a multiplexer that supports the IEEE C37.94 interface, then “**IEEE C37.94**” should be selected otherwise the selection should be “**standard**”. This setting applies to both communications channels - they cannot be set independently. If this setting is changed, the relay must be power cycled before it will take effect.

1.22.2.4 InterMiCOM^{64} Communications Baud Rate

The baud rate for communication over channel 1 (and channel 2 where fitted) can be selected (independently) between 56kbits/s and 64kbits/s. For direct fiber connection 64kbits/s should be selected. If MiCOM P590 units are being used to interface to a telecommunications network, the setting will be dictated by the network. In general, 56kbits/s is only required when using the P592 V.35 interface. This setting is hidden if the IEEE C37.94 mode has been selected.

1.22.2.5 InterMiCOM^{64} Communications Clock Source

The clock source for communication channel 1 (and channel 2 where fitted) can be selected (independently) between "**internal**" and "**external**". For direct fiber connection "**internal**" should be selected. If MiCOM P590 units are being used to interface to a telecommunications network, the setting will be dictated by the network. In general, the "**external**" setting will be used when connecting to a telecommunications network, since the network will normally provide a clock master.

This setting is hidden if the IEEE C37.94 mode has been selected.

1.22.2.6 InterMiCOM^{64} IEEE C37.94 Channel Selection

This setting is only visible if the IEEE C37.94 mode has been selected. It allows the channels to be assigned to a particular channel presented by the interface. Setting it to Auto enables the relay to configure itself to match the multiplexer.

1.22.2.7 InterMiCOM^{64} Communications Fail Timer

The "**Comm Fail Timer**" sets how long after a communications failure the alarm will be issued. In this context, a communications failure is defined as no messages received during the channel timeout period, or the alarm level being exceeded.

1.22.2.8 InterMiCOM^{64} Communications Failure Mode

The "**Comm Fail Mode**" setting applies only to relays configured for dual redundant or three-terminal configuration. It prescribes what combination of failures on the two communications channels is used to flag an alarm.

1.22.2.9 InterMiCOM^{64} Channel Timeout

If an InterMiCOM^{64} command has been set to revert to a default value after a communications failure, this timer sets how long will elapse before the defaults are applied.

1.22.2.10 InterMiCOM^{64} Propagation Delay Statistics

The "**Prop Delay Stats**" setting can be either enabled or disabled. When enabled The "**Max Ch Prop Delay**" settings for communications channel 1 (and 2 if fitted) become visible. These are settings whereby, if InterMiCOM^{64} messages take longer to be received than the setting value, the message can be rejected.

1.22.2.11 InterMiCOM^{64} Command Type

Each of the InterMiCOM^{64} commands can be set via the "**IMn Cmd Type**" setting (n=1-8) to be conditioned for either direct transfer tripping (setting = "**Direct**") or for use in a blocking or permissive scheme (setting = "**Permissive**").

Note	*There are 8 of these settings, one for each of eight InterMiCOM^{64} commands. The 8 settings are applied the same to the 8 InterMiCOM^{64} commands on Channel 1 as to the 8 InterMiCOM^{64} commands on Channel 2, so that if "**IM1 Cmd Type**" is set to "**Direct**", then IM1 channel 1 and IM1 channel2 with both be conditioned for direct transfer tripping.*

1.22.2.12 InterMiCOM^{64} Fallback Mode

Each of the InterMiCOM^{64} command can be set via the "**IMn FallBackMode**" setting (n=1-8) to define its behavior under communications failure conditions. They can be programmed to either latch the state of the last good command received, or they can revert to a default state (either 1 or 0) defined in the "**IMn DefaultValue**" setting (n=1-8).

Note	*There are 8 of each of these settings, one for each of eight InterMiCOM64 commands. The 8 settings are applied the same to the 8 InterMiCOM64 commands on Channel 1 as to the 8 InterMiCOM64 commands on Channel 2.*

1.22.2.13 InterMiCOM^{64} Communications Alarm Management

Due to the criticality of InterMiCOM^{64} communications for correct scheme performance, there is an extensive regime to monitor signal quality and integrity, generate and report alarms. For most applications, the alarming supplied as standard should satisfy the needs of the scheme. For some applications, however, it may be necessary to provide additional qualifications using the programmable scheme logic. To do this, it is necessary to understand the concepts behind the alarm signals and their implementation in the MiCOM P443/P446 relay.

Fundamental to the implementation of scheme logic in the MiCOM Px4x series of relays is the concept of the DDB introduced earlier. The complete list of DDB signals applicable to InterMiCOM^{64} communications are described in section 1.22.2.14 below.

1.22.2.14 InterMiCOM^{64} DDB Signal List

The DDB signals applicable to the optional InterMiCOM^{64} feature are tabulated below. (For a complete list of all DDB signals applicable to the relay please refer to the Programmable Logic (PL) section of this Technical Guide).

DDB No.	English Text	Description
291	Test Loopback	Indicates that the local relay has been selected to Loopback mode (internal or external) in the "Commission Tests" options.
292	Test IM64	Indicates that the local relay has been selected to Test mode in the "Commission Tests" options.
311	Signaling Fail	Indicates when the local receive signal is totally lost, or exceeds the alarm threshold, on either channel 1 or channel 2.
337	Comms Changed	Indicates that the "Comms Mode" setting has been changed between Standard and IEEEC37.94 or vice versa. The relay must be power-cycled to remove this alarm and activate the new communication mode.
315	IEEE C37.94	Indicates that one or more IEEE C37.94 communication alarms are currently active. (IEEE C37.94 alarms are DDB # 1123 - 1126 and DDB # 1133 - 1136. This signal is only used when the "Comms Mode" is selected to IEEE C37.94.
314	IM64 Scheme Fail	Indicates when the communications between the relays has been compromised and therefore IM64 doesn't work. For 2-ended schemes, this is functionally identical to the Signaling Fail DDB signal (DDB # 285). For 3-ended schemes, this is only active when it is no longer possible to provide communications even allowing for pass through mode i.e. more than one link has failed.
96	IM64 Ch1 Input 1	Input DDB signal used in the PSL which is the receive signal for Channel 1, bit 1.
97 - 103	IM64 Ch1 Input 2 … 8	Input DDB signal used in the PSL which is the receive signal for Channel 1, bit 2 to 8.
104	IM64 Ch2 Input 1	Input DDB signal used in the PSL which is the receive signal for Channel 2, bit 1.

DDB No.	English Text	Description
105 - 111	IM64 Ch2 Input 2 … 8	Input DDB signal used in the PSL which is the receive signal for Channel 2, bit 2 to 8.
112	IM64 Ch1 Output1	Output DDB signal used in the PSL which is the transmit signal for Channel 1, bit 1.
113 - 119	IM64 Ch1 Output2 … 8	Output DDB signal used in the PSL which is the transmit signal for Channel 1, bit 2 to 8.
120	IM64 Ch2 Output1	Output DDB signal used in the PSL which is the transmit signal for Channel 2, bit 1.
121 - 127	IM64 Ch2 Output 2 … 8	Output DDB signal used in the PSL which is the transmit signal for Channel 2, bits 2 to 8.
1123	Ch1 Mux Clk	Output DDB signal used to indicate that the frequency of the signal on Channel 1 is outside the frequency expected by the multiplexer. This signal is only used when the “Comms Mode” is selected to IEEE C37.94.
1124	Ch1 Signal Lost	Output DDB signal used to indicate that the multiplexer has lost the signal over channel 1. i.e. no receive information on Channel 1. This signal is only used when the “Comms Mode” is selected to IEEE C37.94.
1125	Ch1 Path Yellow	Output DDB signal used to indicate that the multiplexer has detected one way communication on Channel 1. i.e. the transmit information is not being received by the remote end on Channel 1. This signal is only used when the “Comms Mode” is selected to IEEE C37.94.
1126	Ch1 Mismatch RxN	Output DDB signal used to indicate that there is a mismatch between the communication settings on the InterMiCOM^{64} Channel 1 and the multiplexer. This signal is only used when the “Comms Mode” is selected to IEEE C37.94.
1127	Ch1 Timeout	Output DDB signal used in the PSL to indicate that no valid messages have been received on Channel 1 during the “Channel Timeout” period (settable).
1128	Ch1 Degraded	Output DDB signal used in the PSL to indicate poor channel quality on Channel 1. This is determined by the percentage of bad messages received on Channel 1 exceeding the “IM Msg Alarm Lvl” setting during the previous 100ms.
1129	Ch1 Passthrough	Output DDB signal used in the PSL to indicate when the Channel 1 signaling bits have been received through Channel 2 because of failure of channel 1. This signal is only relevant for 3 ended signaling schemes and is part of the “self-healing” capability.
1133	Ch2 Mux Clk	Output DDB signal used to indicate that the frequency of the signal on Channel 2 is outside the frequency expected by the multiplexer. This signal is only used when the “Comms Mode” is selected to IEEE C37.94.
1134	Ch2 Signal Lost	Output DDB signal used to indicate that the multiplexer has lost the signal over channel 2. i.e. no receive information on Channel 2. This signal is only used when the “Comms Mode” is selected to IEEE C37.94.

DDB No.	English Text	Description
1135	Ch2 Path Yellow	Output DDB signal used to indicate that the multiplexer has detected one way communication on Channel 2. i.e. the transmit information is not being received by the remote end on Channel 2. This signal is only used when the "Comms Mode" is selected to IEEE C37.94.
1136	Ch2 Mismatch RxN	Output DDB signal used to indicate that there is a mismatch between the communication settings on the InterMiCOM^{64} Channel 2 and the multiplexer. This signal is only used when the "Comms Mode" is selected to IEEE C37.94.
1137	Ch2 Timeout	Output DDB signal used in the PSL to indicate that no valid messages have been received on Channel 2 during the "Channel Timeout" period (settable).
1138	Ch2 Degraded	Output DDB signal used in the PSL to indicate poor channel quality on Channel 2. This is determined by the percentage of bad messages received on Channel 2 exceeding the "IM Msg Alarm Lvl" setting during the previous 100ms.
1139	Ch2 Passthrough	Output DDB signal used in the PSL to indicate when the Channel 2 signaling bits have been received through Channel 1 because of failure of channel 2. This signal is only relevant for 3 ended signaling schemes and is part of the "self-healing" capability.
338	Max Prop Alarm	Output DDB set if the communications propagation delay on either channel 1 or channel 2 exceeds its setting.
1386	Max Ch1 PropDelay	Output DDB set if the communications propagation delay on channel 1 exceeds its setting.
1387	Max Ch2 PropDelay	Output DDB set if the communications propagation delay on channel 2 exceeds its setting.

Figure 50 - DDB signals applicable to the optional InterMiCOM^{64} feature

1.22.2.15 InterMiCOM^{64} Communications Alarm Logic

The operation of the main alarm DDB signals associated with InterMiCOM^{64} are shown in the conceptual diagrams (Figure 51 and Figure 52). It should be recognized that some of the signals are setting/hardware dependent (for example, Channel 2 alarms will not be available on a simple 2-terminal single communications link application).

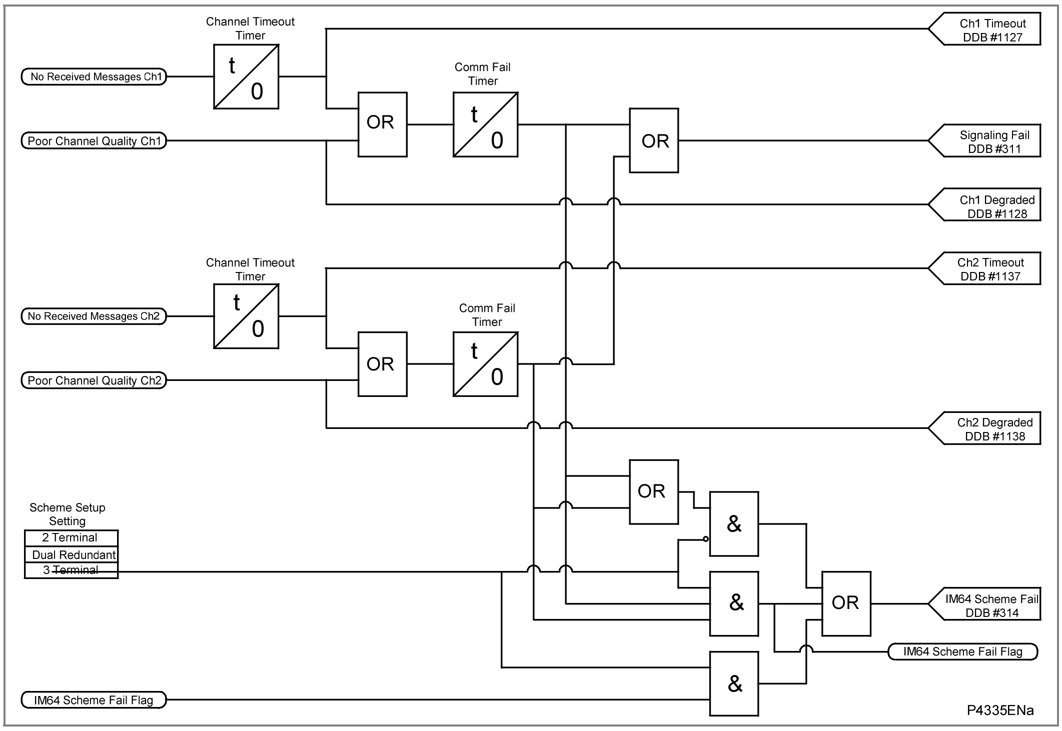

Channel Timeout Timer
No Received Messages Ch1
t
0
Comm Fail Timer
OR
Poor Channel Quality Ch1
Ch1 Timeout DDB #1127
Signaling Fail DDB #311
Ch1 Degraded DDB #1128
Channel Timeout Timer
Ch2 Timeout DDB #1137
No Received Messages Ch2
Comm Fail Timer
Poor Channel Quality Ch2
Ch2 Degraded DDB #1138
Scheme Setup Setting
2 Terminal
Dual Redundant
3 Terminal
&
IM64 Scheme Fail DDB #314
IM64 Scheme Fail Flag
IM64 Scheme Fail Flag
P4335ENa

Figure 51 - InterMiCOM^{64} channel fail and scheme fail conceptual logic

The messages received on each channel are individually assessed for quality to ensure that the InterMiCOM^{64} signaling scheme is available for use. In the event of no messages being received for a period equal to the "**Channel Timeout**" setting, or the signal quality falling below a defined value then DDB signals will be activated as shown in the figure.

Poor quality is indicated if the percentage of incomplete messages exceeds the "**IM Msg Alarm Lvl**" setting within a 100ms period (rolling window), or if the communications propagation time of the InterMiCOM^{64} message exceeds the "**Ch Max PropDelay**" (if the "**Prop DelayStats**" setting is enabled), or if (in IEEE C37.94 configuration only, and not shown on the diagram) the "**Ch Mux Clk**" flag is set to indicate an incorrect baud rate.

If either the "**Ch Timeout**", or the "**Ch Degraded**" signal persists in the alarmed state for more than the duration of the "**Comm Fail Timer**" setting, then the "**Signaling Fail**" signal will be raised and indicated on the relay according to the conditions set in the "**Comm Fail Mode**" setting of the relay.

In the case of two-ended schemes (including dual redundant schemes), the "**IM64 Scheme Fail**" signal will be generated at the same time as the "**Signaling Fail**" signal. However, for three-terminal applications, the "**IM64 Scheme Fail**" signal gives an indication of when the full set of signaling bits cannot be processed by the scheme. Due to the self-healing nature of the three-terminal application, this occurs when both channels at any one end are not receiving good signals. This will generate a flag within the InterMiCOM^{64} message structure which is passed to both remote ends, as well as generating the local "**IM64 Scheme Fail**" signal. By this method, in three-terminal applications the scheme fail indication will be raised at all three ends.

It should be noted that the scheme fail signaling is generated by the inability of the relays to receive messages through communication failure. That is to say that a transmitting relay will only know that its communication to a remote relay is in a failed state if it receives notification from the remote relay that that is the case. If a relay in the scheme is put into test mode, the communication failure information is not passed on to the remote ends. In this instance then it might be that the communications are in a failed state, but that there is no indication to the remote relays that this is the case. Should this cause operational issues then it may be necessary to include other signals to enable more precise indication of scheme failure, as described in the application (AP) section of this Technical Guide.

In addition to the main InterMiCOM^{64} channel fail and scheme fail conceptual logic in the figure above, there are number of additional alarm DDB signals associated with test modes, reconfiguration for 3-terminal schemes, and the communication mode (standard vs IEEE C37.94). These are outlined in the two figures below:

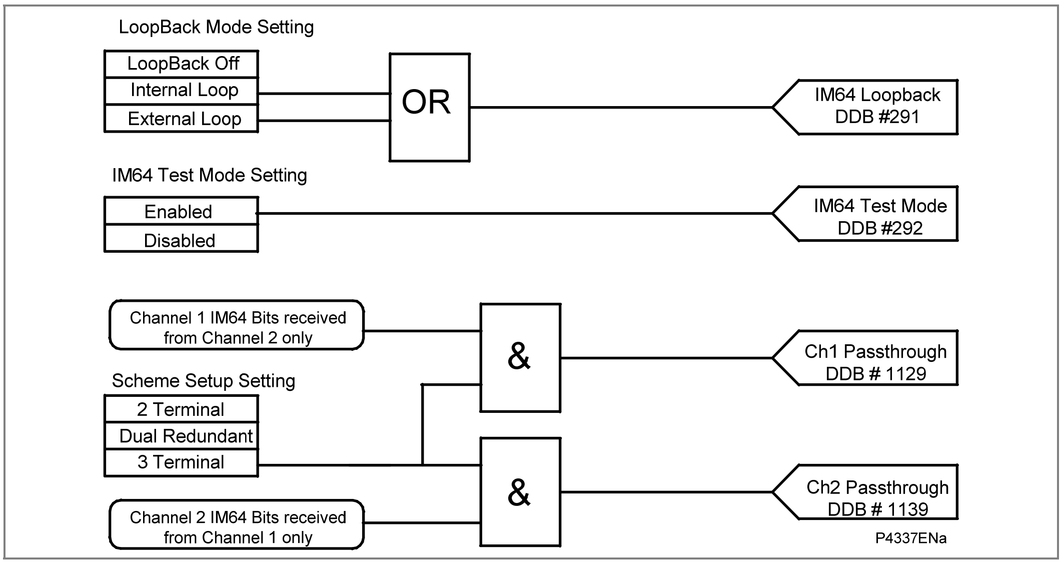

LoopBack Mode Setting
LoopBack Off
Internal Loop
External Loop
OR
IM64 Loopback DDB #291
IM64 Test Mode Setting
Enabled
Disabled
IM64 Test Mode DDB #292
Channel 1 IM64 Bits received from Channel 2 only
&
Ch1 Passthrough DDB # 1129
Scheme Setup Setting
2 Terminal
Dual Redundant
3 Terminal
&
Ch2 Passthrough DDB # 1139
Channel 2 IM64 Bits received from Channel 1 only
P4337ENa

Figure 52 - InterMiCOM^{64} general alarm signals (conceptual logic)

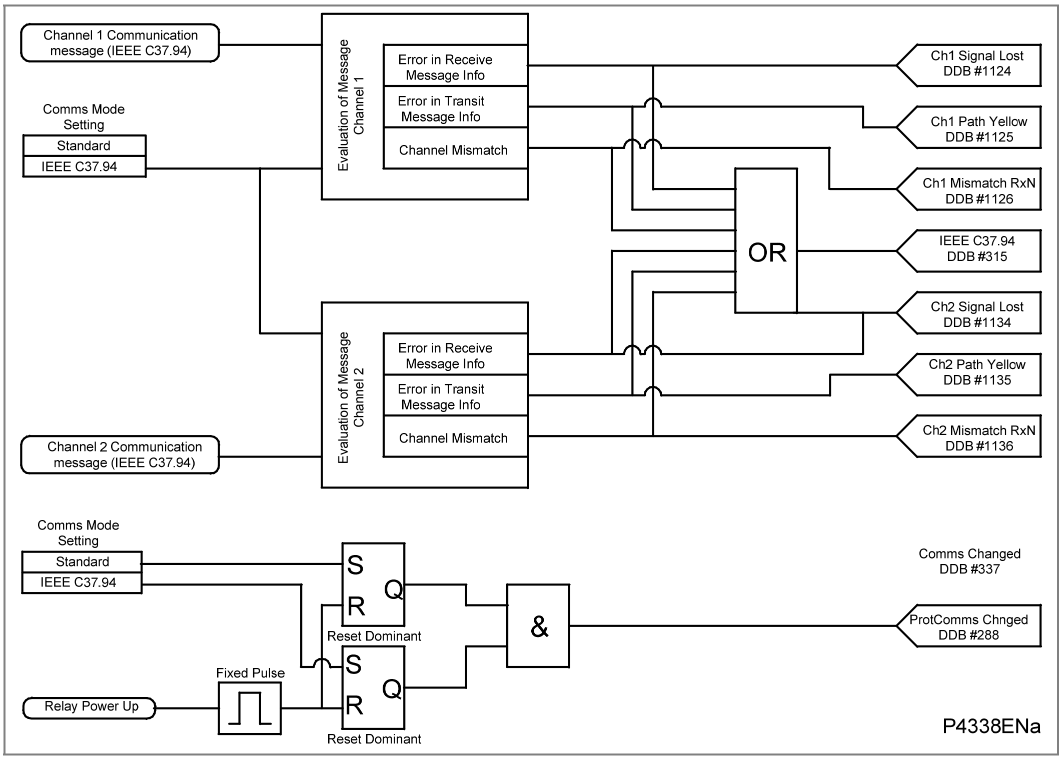

Channel 1 Communication message (IEEE C37.94)
Comms Mode Setting
Standard
IEEE C37.94
Evaluation of Message Channel 1
Error in Receive Message Info
Error in Transit Message Info
Channel Mismatch
Ch1 Signal Lost DDB #1124
Ch1 Path Yellow DDB #1125
Ch1 Mismatch RxN DDB #1126
OR
IEEE C37.94 DDB #315
Ch2 Signal Lost DDB #1134
Ch2 Path Yellow DDB #1135
Ch2 Mismatch RxN DDB #1136
Evaluation of Message Channel 2
Error in Receive Message Info
Error in Transit Message Info
Channel Mismatch
Channel 2 Communication message (IEEE C37.94)
Comms Mode Setting
Standard
IEEE C37.94
S
R
Q
Reset Dominant
&
Comms Changed DDB #337
ProtComms Chnged DDB #288
Fixed Pulse
S
R
Q
Reset Dominant
Relay Power Up
P4338ENa

Figure 53 - InterMiCOM^{64} communications mode and IEEE C37.94 alarm signals

The majority of signals described in Figure 54 are associated with the IEEE C37.94 communications mode and will not be activated if the standard communication mode is selected. As can be seen from the "**Comms Changed DDB**" logic, switching between the different communication modes requires a power-cycle to be performed.

1.22.2.16 InterMiCOM^{64} Two Ended Scheme Extended Supervision

Referring to the logic in section 0, it may be seen that for two-ended applications, the "**Signaling Fail**" and "**IM64 Scheme Fail**" signals operate together. As such, the basic indications available on each relay should be considered as local-end indications only. If remote indication is needed to assure scheme functionality, it is necessary to use additional signals to communicate the status to the remote end. One method of performing this is shown in Figure 54:

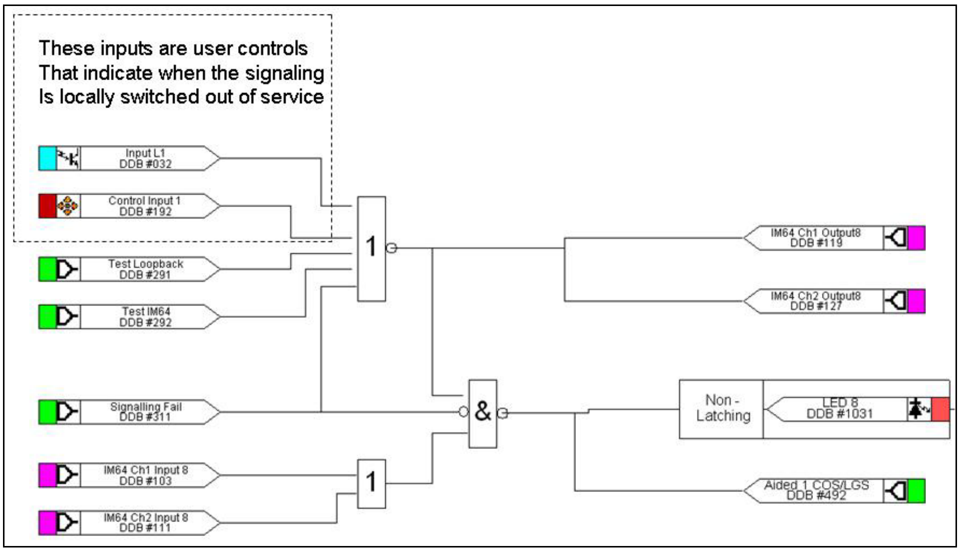

These inputs are user controls
That indicate when the signaling
Is locally switched out of service
Input L1
DDB #032
Control Input 1
DDB #192
Test Loopback
DDB #291
Test IM64
DDB #292
Signalling Fail
DDB #311
IM64 Ch1 Input 8
DDB #103
IM64 Ch2 Input 8
DDB #111
1
&
1
IM64 Ch1 Output8
DDB #119
IM64 Ch2 Output8
DDB #127
Non - Latching
LED 8
DDB #1031
Aided 1 COS/LGS
DDB #492

Figure 54 - InterMiCOM^{64} two ended scheme extended supervision

In this example scheme, a number of signals are used to permanently pass an InterMiCOM^{64} signal to the remote end. These signals take account of the local ability to receive InterMiCOM^{6}4 messages, local test/loopback modes and any other external methods of switching the signaling scheme out of service. If any of these driving signals are energized, then the InterMiCOM^{64} message is reset (a "**0**" sent on InterMiCOM^{64} bit 8), causing both ends to raise an alarm (LED 8) and/or switch the aided scheme out of service due to loss of channel.

It should be noted that the logic presented above is intended only as an example. It is likely that some customization would be required to suit actual application requirements.

1.22.2.17 InterMiCOM^{64} Three Ended Scheme Extended Supervision

The example scheme shown in sub-clause 1.22.2.16 can be extended to cover 3-terminal applications. In this case the "**IM64 Scheme Fail**" signal that is automatically communicated to all ends of the scheme is incorporated rather than the "**Signaling Fail**" of the previous example.

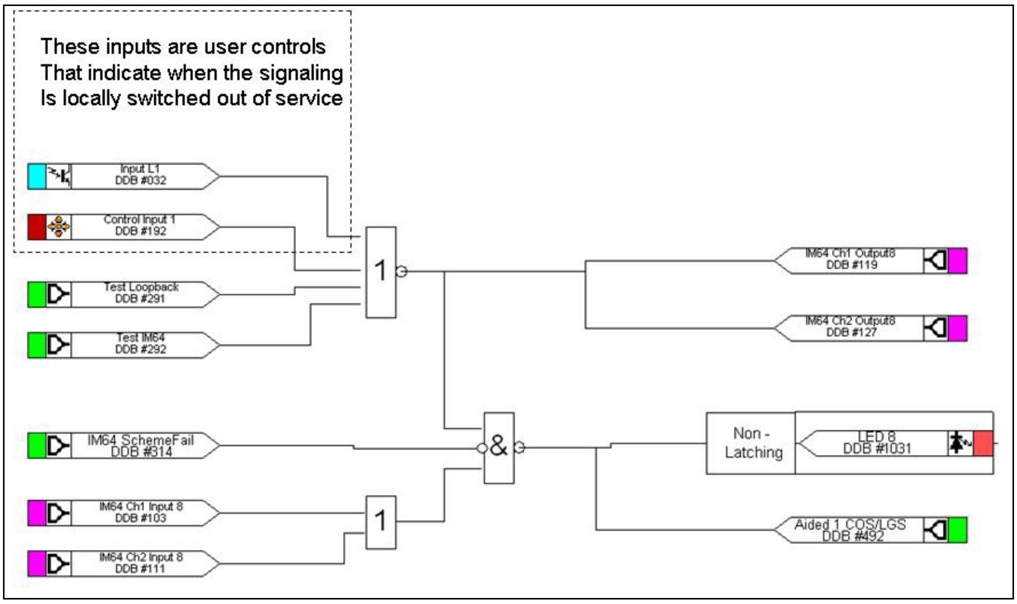

These inputs are user controls
That indicate when the signaling
Is locally switched out of service
Input L1
DDB #032
Control Input 1
DDB #192
Test Loopback
DDB #291
Test IM64
DDB #292
IM64 SchemeFail
DDB #314
IM64 Ch1 Input 8
DDB #103
IM64 Ch2 Input 8
DDB #111
1
&
1
IM64 Ch1 Output8
DDB #119
IM64 Ch2 Output8
DDB #127
Non - Latching
LED 8
DDB #1031
Aided 1 COS/LGS
DDB #492

Figure 55 - Triangulated InterMiCOM^{64} application

In this example if both channels at any one end fail to receive information, then this will be communicated to the other ends with an alarm raised and aided scheme switched out of service. The example above takes into account the test modes and local switching, such that the scheme will be signaled out of service at all ends if one end is locally disabled.

Again, it should be noted that the logic presented above is intended only as an example. It is likely that some customization would be required to suit actual application requirements.

1.22.3 InterMiCOM^{64} Communications Link Options

A number of communications options are available, for the communication channels between MiCOM P443/P446 system ends. The various connection options are shown below. Choosing between each of these options will depend on the type of communications equipment that is available.

- Where existing suitable multiplexer communication equipment is installed for other communication between substations, the 850nm option together with an appropriate ITU-T compatible electrical interface (P590 series unit) should be selected to match the existing multiplexer equipment. Where an IEEE C37.94 compatible multiplexer is installed the 850nm option should be configured to interface directly to the multiplexer.
- Where no multiplexer is installed, a direct 1300nm optical fiber connection can be used. The type of fiber used (multi-mode or single-mode) will be determined by the distance between the ends of the MiCOM P443/P446 relay scheme.

In any configuration, except the IEEE C37.94, the data rate may be selected as either 64kbit/sec or 56kbit/sec.

1.22.3.1 InterMiCOM^{64} Optical Fiber Communications Link Options

The list of all available fiber channel options is:

•	850nm multi-mode	always two channels supplied as standard
•	1300nm multi-mode	one channel only
•	1300 nm multi-mode	both channels (CH1 and CH2)

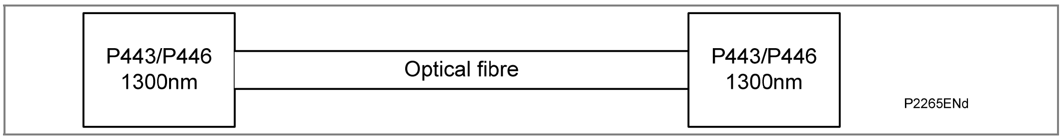
- 1300 nm single-mode one channel only
- 1300 nm single-mode both channels (CH1 and CH2)

Direct Optical Fiber Link, 850nm Multi-Mode Fiber

It is possible to connect two MiCOM P443/P446 relays using 850nm multi-mode fiber but since the above configuration is typically suitable for connection only up to 1km, it is unlikely that this application will ever be applied in practical applications. This interface is, however, the most commonly supplied, since it is suitable for connection using the P590 series of interface units and/or an interface compliant with the IEEE C37.94 standard described later.

Direct Optical Fiber Link, 1300nm Multi-Mode Fiber

The relays are connected directly using two 1300nm multi-mode fibers for each signaling channel. Multi-mode fiber type 50/125μm or 62.5/125μm is suitable. BFOC/2.5 type fiber optic connectors are used.

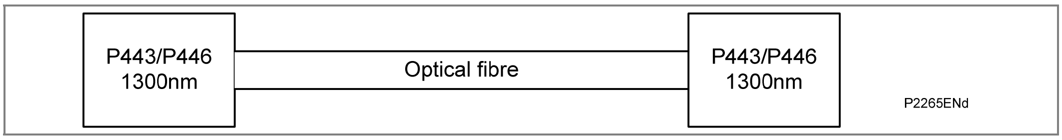


This is typically suitable for connection up to approximately 50km (from April 2008).

Pre-April 2008 relays were suitable for connection up to approximately 30km.

Direct Optical Fiber Link, 1300nm Single-Mode Fiber

The relays are connected directly using two 1300nm single-mode fibers, type 9/125μm for each signaling channel. BFOC/2.5 type fiber optic connectors are used.



This is typically suitable for connection up to approximately 100km (from April 2008).

Pre-April 2008 relays were suitable for connection up to approximately 60km.

IEEE C37.94 Interface to Multiplexer

A relay with 850nm short haul optical interface is connected directly to the multiplexer by 850nm multi-mode optical fiber. Multi-mode fiber type 50/125μm or 62.5/125μm is suitable. BFOC/2.5 type fiber optic connectors are used.

The setting Comms Mode should be set to IEEE C37.94.

Note *The relay must be powered off and on before this setting change becomes effective. The IEEE C37.94 standard defines an N*64kbits/s standard where N can be 1 - 12. N can be selected on the relay or alternatively set to Auto in which case the relay will configure itself to match the multiplexer.*

1.22.3.2 InterMiCOM^{64} Connection via P590 Series Optical Fiber to Electrical Interface Units

In order to connect the relays via a pulse code modulation (PCM) multiplexer network or digital communication channel, Type P590 type interface units are required. The following interface units are available:

- P591 interface to multiplexing equipment supporting ITU-T (formerly CCITT) Recommendation G.703 co-directional electrical interface
- P592 interface to multiplexing equipment supporting ITU-T Recommendation V.35 electrical interface

- P593 interface to multiplexing or ISDN equipment supporting ITU-T Recommendation X.21 electrical interface

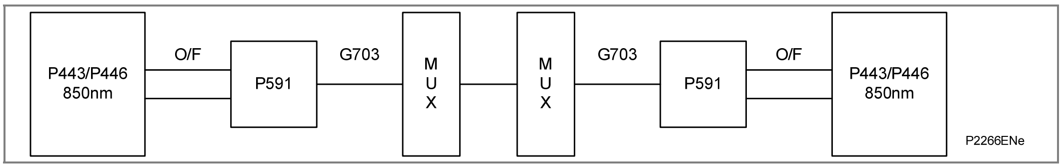
The data rate for each unit can be 56kbits/s or 64kbits/s as required for the data communications link.

One P590 unit is required per relay per data channel (i.e. for each transmit and receive signal pair). It provides optical to electrical and electrical to optical signal conversion between the MiCOM P443/P446 relay and the multiplexer. The interface unit should be located as close to the PCM multiplexer as possible, to minimize any effects on the data of electromagnetic noise or interference. The units are housed in a 20TE MiCOM case.

Fiber optic connections to the unit are made through BFOC/2.5 type connectors, more commonly known as '**ST**' connectors. The optical characteristics are similar to the MiCOM P443/P446 850nm multi-mode fiber optic interface.

Multiplexer Link with G.703 using Type P591 Interface

A relay with 850nm short haul optical interface is connected to a P591 unit by two cores of 850nm multi-mode optical fiber. Multi-mode fiber type 50/125μm or 62.5/125μm is suitable. BFOC/2.5 type fiber optic connectors are used. The P591 unit converts the data between optical fiber and ITU-T compatible G.703 co-directional electrical interface. The G.703 output must be connected to an ITU-T compatible G.703 co-directional channel on the multiplexer.



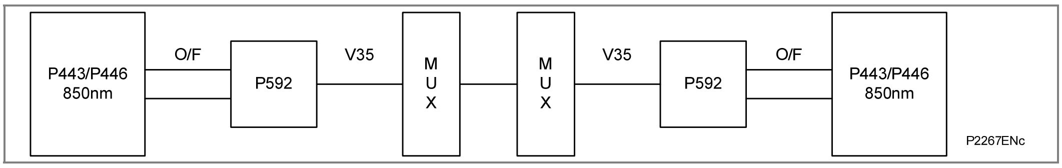
The G.703 signals are isolated by pulse transformers to 1kV.

Since the G.703 signals are only of ±1V magnitude, the cable connecting the P591 unit and the multiplexer must be properly screened against electromagnetic noise and interference. The interface cable should consist of twisted pairs of 24AWG, overall shielded, and have a characteristic impedance of about 120Ω. It is generally recommended that the interface cable shield should be connected to the multiplexer frame ground only. The choice of grounding depends however on local codes and practices.

Electrical connections to the P591 unit are made via a standard 28-way Midos connector. Please refer to Installation section (P44y/EN IN) for the External Connection Diagrams. The MiCOM P443/P446 must be set with Clock Source as '**External**'.

Multiplexer Link with V.35 using Type P592 Interface

A relay with 850nm short haul optical interface is connected to a P592 unit by two cores of 850nm multi-mode optical fiber. Multi-mode fiber type 50/125μm or 62.5/125μm is suitable. BFOC/2.5 type fiber optic connectors are used. The P592 unit converts the data between optical fiber and ITU-T compatible V.35 electrical interface. The V.35 output must be connected to an ITU-T compatible V.35 channel on the multiplexer.



Connections of V.35 signals to the P592 unit are made via a standard female 34 pin '**M**' block connector. Since the V.35 signals are either of ±0.55V or ±12V magnitude, the cable connecting the unit to the multiplexer must be properly screened against electromagnetic noise and interference. The interface cable should consist of twisted pairs of wires which are shielded, and have a characteristic impedance of about 100Ω. It is generally recommended that the interface cable shield is connected to the multiplexer frame ground. The choice of grounding depends however on local codes and practices.

The P592 front panel consists of five indicating LEDs and six DIL (dual in line) switches. The switch labeled ‘**Clockswitch**’ is provided to invert the V.35 transmit timing clock signal if required.

The switch labeled ‘**Fiber-optic Loopback**’ is provided to allow a test loopback of the communication signal across the fiber optic terminals. When switched on, the red LED labeled **'Fiber-optic Loopback'** is illuminated.

The switch labeled ‘**V.35 Loopback**’ is provided to allow a test loopback of the communication signal across the V.35 terminals. It loops the incoming V.35 ‘**Rx**’ data lines internally back to the outgoing V.35 ‘**Tx**’ data lines. When switched on, the red LED labeled ‘**V.35 Loopback**’ is illuminated.

The switch labeled ‘**DSR**’ is provided to select/ignore the DSR (Data Set Ready) handshaking control signal. The red LED labeled DSR Off is extinguished either when DSR is asserted or when overridden by setting the DSR switch On.

The switch labeled ‘**CTS**’ is provided to select/ignore the CTS (Clear To Send) handshaking control signal. The red LED labeled CTS Off is extinguished either when CTS is asserted or when overridden by setting the CTS switch On.

The switch labeled ‘**Data Rate**’ is provided to allow the selection of 56 or 64k bits/s data rate, as required by the PCM multiplexing equipment.

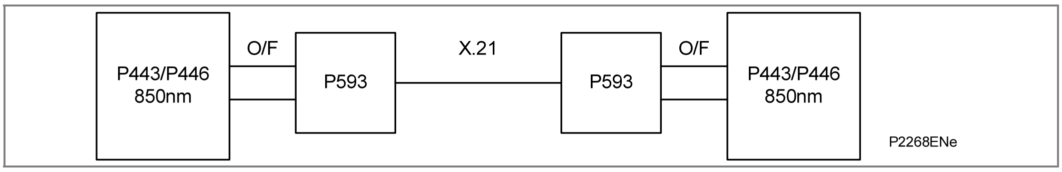
The LED labeled ‘**Supply Healthy**’ is green and provides indication that the unit is correctly powered.

Please refer to the Installation section (P44y/EN IN) for the External Connection Diagrams. The timing for the InterMiCOM^{64} communication channel may be set either with Clock Source as ‘**External**’ for a multiplexer network which is supplying a master clock signal, or with Clock Source as ‘**Internal**’ for a multiplexer network recovering signal timing from the equipment.

Multiplexer Link with X.21 using Type P593 Interface

The P593 unit supports the ITU-T Recommendation X.21 interface. It is approved as line interface equipment by the British Approvals Board for Telecommunications (BABT) for connection to the services described in this section; License Certificate Number NS/1423/1/T/605362.

A relay with 850nm short haul optical interface is connected to a P593 unit by two cores of 850nm multi-mode optical fiber. Multi-mode fiber type 50/125µm or 62.5/125µm is suitable. BFOC/2.5 type fiber optic connectors are used. The P593 unit converts the data between optical fiber and ITU-T compatible X.21 electrical interface. The X.21 output must be connected to an ITU-T compatible X.21 channel on the multiplexer or ISDN digital data transmission link.



The relays require a permanently open communications channel. Consequently, no communications handshaking is required, and it is not supported in the P593 unit. The signals supported are shown in the table below.

ITU-T Recommendation X.21 is closely associated with EIA specifications RS422 and RS449. The P593 can be used with RS422 or RS449 communications channels which require only the signals shown below.

ITU-T Designation	Description	Connector Pin	Direction
-	Case earth	1	-
G	Common return	8	-
T	Transmit data A	2	From P593
T	Transmit data B	9	From P593
R	Receive data A	4	To P593
R	Receive data B	11	To P593
S	Signal element timing A	6	To P593
S	Signal element timing B	13	To P593

Table 8 - RS422 or RS449 communications channel signals

Connections of X.21 signals to the P593 unit are made via a standard male 15 way D-type connector, wired as a DTE device. The interface cable should consist of twisted pairs of 24AWG, overall shielded, and have a characteristic impedance of about 100Ω. It is generally recommended that the interface cable shield is connected to the multiplexer frame ground. The choice of grounding depends however on local codes and practices.

Please refer to the Installation section (P44y/EN IN) for the External Connection Diagrams.

The timing for the InterMiCOM^{64} communication channel must be set with Clock Source as '**External**'.

The P593 front panel consists of four indicating LEDs and two switches.

The LED labeled '**Supply healthy**' is green and provides indication that the unit is correctly powered.

The LED labeled '**Clock**' is green and provides indication that an appropriate X.21 signal element timing signal is presented to the unit.

One of the switches is labeled '**Fiber Optic Loopback**'. This is provided to allow a test loopback of the communication signal across the fiber optic terminals. When switched on, the red LED labeled '**Fiber Optic Loopback**' is illuminated.

The second switch is labeled '**X.21 Loopback**'. This is provided to allow a test loopback of the communication signal across the X.21 terminals. It loops the incoming X.21 '**Rx**' data lines internally back to the outgoing X.21 '**Tx**' data lines, and also loops the incoming fiber optic '**Rx**' data line (via the X.21 signal conversion circuitry) back to the outgoing fiber optic '**Tx**' data line. When switched on, the red LED labeled '**X.21 Loopback**' is illuminated.

1.22.3.3 InterMiCOM^{64} Connection over Unconditioned Pilot Wires

It is possible to deploy InterMiCOM^{64} on certain circuits where unconditioned 2-wire or 4-wire pilots are available for communication. To achieve this requires a combination of P590 series optical fiber to electrical interface units together with third-party baseband modems. The application will be restricted by the length and quality of the pilots, with maximum pilot lengths restricted to less than 20km.

When considering applying a scheme based on InterMiCOM^{64}, P590, and baseband modems, the impact of the modem retrain time on the application needs to be understood before making the decision. Unconditioned 2-wire and 4-wire pilots are generally routed in proximity to the electrical power transmission and distribution feeders that they are helping to protect. As such, they are partial to electro-magnetic interference during switching or fault conditions on the power system. The induced interference on the pilots can cause disruption of the communications signals, and if this is sufficient to cause the synchronization of the communications to be lost, then the modems will have to re-synchronize, or retrain.

Note	*If the possibility of communications breaks of up to 10 seconds during switching or fault conditions on the power system cannot be tolerated by the InterMiCOM^{64} application, then the decision to implement a scheme using pilot wire circuits should be reviewed.*

Pilot Isolation

During primary earth faults, the strong magnetic field generated can induce a significant voltage between the pilots and ground (longitudinal voltage). To prevent damage to any equipment connected to the pilot circuit, it must be ensured that the modem can provide an adequate isolation barrier between the pilot itself and all other electrically isolated circuits. Although it may be difficult to accurately predict the induced pilot voltage during an earth fault, the following equations can be used to give an approximation:

Induced voltage for un-screened pilots $\approx 0.3 \times I_F \times L$

Induced voltage for screened pilots $\approx 0.1 \times I_F \times L$

Where:
I_F = Maximum prospective earth fault current in amperes
L = Length of pilot circuit in miles

In cases where the calculated voltage exceeds, typically 60% of the relay/modem isolation level, additional isolation must be added. Schneider Electric offer the PCM-FLÜ 10kV or 20kV isolating transformers for use in conjunction with such baseband modems. The choice of 10kV or 20kV will depend upon the predicted magnitude of the induced voltage.

Note	*The PCM-FLÜ isolating transformer has "**a**", "**m**" and "**b**" taps on both primary and secondary windings. For all InterMiCOM^{64} applications, connection must be made between taps '**a**' and '**m**', since the frequency range of this winding extends to 2MHz. Connection between '**a**' and '**b**' may result in unreliable communications as the maximum frequency for this tap configuration is 6kHz. Connection to '**a**' and '**m**' taps must be adhered to on both primary and secondary so as to maintain a 1:1 ratio.*

Baseband Modem and P590 Specification

Deployment of the Patton "**Campus**" 1092A baseband modem has been demonstrated with the MiCOM relays and a scheme based on this is presented below.

The Patton "**Campus**" 1092A baseband modem offers a relatively short retrain time (by baseband modem standards), but it should be noted that this can be as long as ten seconds and the effect of this should be recognized as per the note in section 1.22.3.3.

On a 2-wire pilot connection a maximum link length of approximately 17km can be achieved. On a 4-wire pilot, approximately 18km is possible. These figures are, however, dependent upon the diameter and quality of the pilot wires. The effect of cable diameter on distance is shown in the following table.

Wire Gauge	Wire Diameter	Maximum Distance (2-wire connection)	Maximum Distance (4-wire connection)
19 AWG	0.9mm	17.2km	18.2km
22 AWG	0.64mm	11.5km	12.1km
24 AWG	0.5mm	8km	8.5km
26 AWG	0.4mm	5.5km	5.7km

Table 9 - Effect of cable diameter on distance

For maximum security and performance it is strongly recommended that the pilots use screened twisted pairs of conductors.

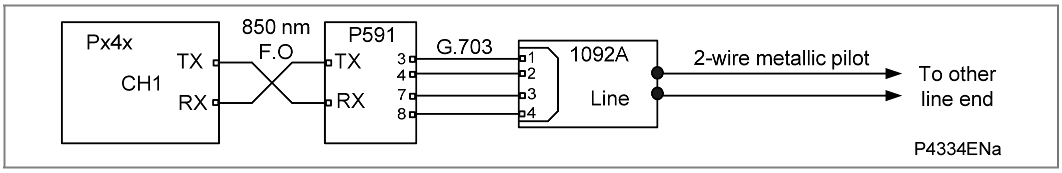
The Campus modem should be specified with a G.703 interface and should be used in conjunction with a MiCOM P591.

Baseband Modem Propagation Delay

The use of a baseband modem will bring an additional propagation delay time that needs to be taken into account. For a 2-wire connection to the Campus modem the additional delay will be 1.02ms. For a 4-wire connection to the Campus modem the additional delay will be 1.08ms.

Baseband Modem and relay Configuration

A scheme configuration using 2-wire connection without additional isolation is shown below:



The MiCOM P443/P446 relays should have their "**IM64 Comms Mode**" set to "**standard**", their data rates set to 64kbits/s, and their clock sources set to external.

One of the Campus modems on the pilot wire should be assigned as a "**master**" and the other assigned as "**slave**". The "**master**" should be set to generate an internal clock, and the "**slave**" should be set for "**receive recovery**". This is achieved by means of setting dual in-line (DIL) switches inside the modem. To implement these settings, the switches should be set as per Table 10 and Table 11:

MASTER								
S1 (on the bottom side of the modem)								
Pin no.	1	2	3	4	5	6	7	8
Setting	1	0	1	0	0	1	1	1
S2 (on the bottom side of the modem)								
Pin no.	1	2	3	4	5	6	7	8
Setting	0	0	0	0	0	1	0	0
S? (inside the interface card)								
Pin no.	1	2	3	4				
Setting	1	0	1	1				

Table 10 - Master switch settings

SLAVE								
S1 (on the bottom side of the modem)								
Pin no.	1	2	3	4	5	6	7	8
Setting	1	0	1	0	0	1	0	1
S2 (on the bottom side of the modem)								
Pin no.	1	2	3	4	5	6	7	8
Setting	0	0	0	0	0	1	0	0
S? (inside the interface card)								
Pin no.	1	2	3	4				
Setting	1	0	1	1				

Table 11 - Slave switch settings

The MiCOM P591 communications interface units do not require any special setting up and the scheme should be now operational.

1.23 Phase Fault Overcurrent Protection

Phase fault overcurrent protection is provided as back-up protection that could be:

- Permanently disabled
- Permanently enabled
- Enabled only in case of VT fuse/MCB failure

In addition, each stage may be disabled by a DDB (463, 464, 465 or 466) “**Inhibit I > x**“

(x = 1, 2, 3 or 4)

It should be noted that phase overcurrent protection is phase segregated, but the operation of any phase is mapped to 3 phase tripping in the default PSL.

The VTS element of the relay can be selected to either block the directional element or simply remove the directional control.

The first two stages can be set either inverse time or definite time only. The third and fourth stages have a DT characteristic only. Each stage can be configured to be directional forward, directional reverse or non-directional.

For the IDMT characteristics the following options are available.

The IEC/UK IDMT curves conform to the following formula:

$$t = T \times \left(\frac{\beta}{(I/Is)^{\alpha} - 1} + L \right)$$

The IEEE/US IDMT curves conform to the following formula:

$$t = TD \times \left(\frac{\beta}{(I/Is)^{\alpha} - 1} + L \right)$$

t = Operation time
β = Constant
I = Measured current
Is = Current threshold setting
α = Constant
L = ANSI/IEEE constant (zero for IEC curves)
T = Time multiplier setting for IEC/UK curves
TD = Time multiplier setting for IEEE/US curves

IDMT Curve Description	Standard	β Constant	α Constant	L Constant
Standard Inverse	IEC	0.14	0.02	0
Very Inverse	IEC	13.5	1	0
Extremely Inverse	IEC	80	2	0
Long Time Inverse	UK	120	1	0
Moderately Inverse	IEEE	0.0515	0.02	0.114
Very Inverse	IEEE	19.61	2	0.491
Extremely Inverse	IEEE	28.2	2	0.1217
Inverse	US-C08	5.95	2	0.18

IDMT Curve Description	Standard	β Constant	α Constant	L Constant
Short Time Inverse	US	0.16758	0.02	0.11858

> *Note* *That the IEEE and US curves are set differently to the IEC/UK curves, with regard to the time setting. A time multiplier setting (TMS) is used to adjust the operating time of the IEC curves, whereas a time dial setting is employed for the IEEE/US curves. The menu is arranged such that if an IEC/UK curve is selected, the '**I> Time Dial**' cell is not visible and vice versa for the TMS setting.*

Table 12 - Curve descriptions, standards and constants

1.23.1 Reset Characteristics for Overcurrent Elements

> *Note* *The IEC/UK inverse characteristics can be used with a definite time reset characteristic, however, the IEEE/US curves may have an inverse or definite time reset characteristic. The following equation can used to calculate the inverse reset time for IEEE/US curves:*

$$\text{tRESET} = \frac{\text{TD x S}}{(1 - \text{M}^2)} \text{ in seconds}$$

Where:

TD = Time dial setting for IEEE curves

S = Constant

M = I/Is Curve Description	Standard	S Constant
Moderately Inverse	IEEE	4.85
Very Inverse	IEEE	21.6
Extremely Inverse	IEEE	29.1
Inverse	US	5.95
Short Time Inverse	US	2.261

Table 13 - Curve descriptions, standards and constants

1.23.2 Directional Overcurrent Protection

The phase fault elements of The MiCOM P443/P446 relays are internally polarized by the quadrature phase-phase voltages, as shown in the table below:

Phase of Protection	Operate Current	Polarizing Voltage
A Phase	IA	VBC
B Phase	IB	VCA
C Phase	IC	VAB

Table 14 - Phase of protection, currents and voltages

Under system fault conditions, the fault current vector will lag its nominal phase voltage by an angle dependent upon the system X/R ratio. It is therefore a requirement that the relay operates with maximum sensitivity for currents lying in this region. This is achieved by means of the relay characteristic angle (RCA) setting; this defines the angle by which the current applied to the relay must be displaced from the voltage applied to the relay to obtain maximum relay sensitivity. This is set in cell "**I>Char Angle**" in the overcurrent menu. On The MiCOM P443/P446 relays, it is possible to set characteristic angles anywhere in the range –95° to +95°.

The functional logic block diagram for directional overcurrent is shown overleaf.

The overcurrent block is a level detector that detects that the current magnitude is above the threshold and together with the respective polarizing voltage, a directional check is performed based on the following criteria:

Directional forward

-90° < (angle(I) - angle(V) - RCA) < 90°

Directional reverse

-90° > (angle(I) - angle(V) - RCA) > 90°

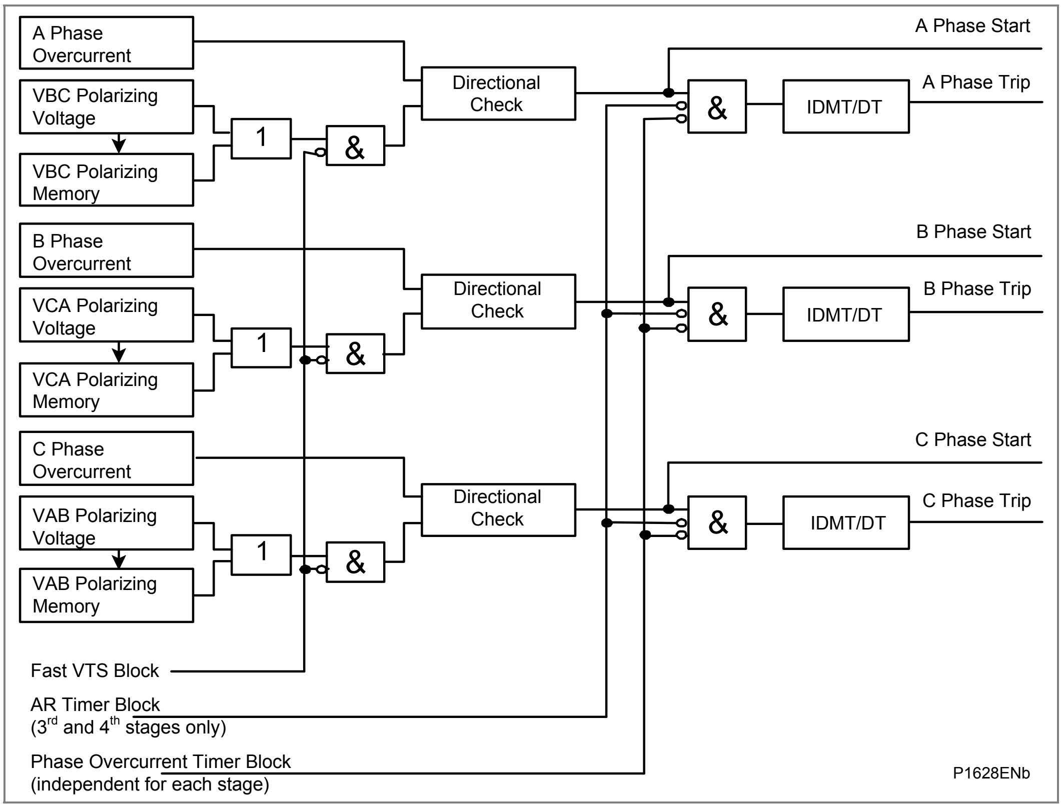

A Phase Overcurrent
VBC Polarizing Voltage
VBC Polarizing Memory
1
&
Directional Check
&
IDMT/DT
A Phase Start
A Phase Trip
B Phase Overcurrent
VCA Polarizing Voltage
VCA Polarizing Memory
1
&
Directional Check
&
IDMT/DT
B Phase Start
B Phase Trip
C Phase Overcurrent
VAB Polarizing Voltage
VAB Polarizing Memory
1
&
Directional Check
&
IDMT/DT
C Phase Start
C Phase Trip
Fast VTS Block
AR Timer Block (3rd and 4th stages only)
Phase Overcurrent Timer Block (independent for each stage)
P1628ENb

Figure 56 - Directional overcurrent logic

Any of the four overcurrent stages may be configured to be directional noting that IDMT characteristics are only selectable on the first two stages. When the element is selected as directional, a VTS Block option is available. When the relevant bit is set to 1, operation of the Voltage Transformer Supervision (VTS), will block the stage if directionalized. When set to 0, the stage will revert to non-directional upon operation of the VTS.

1.24 Synchronous Polarization

For a close up three-phase fault, all three voltages will collapse to zero and no healthy phase voltages will be present. For this reason, The MiCOM P443/P446 relays include a synchronous polarization feature that stores the pre-fault voltage information and continues to apply it to the directional overcurrent elements for a time period of 3.2 seconds. This ensures that either instantaneous or time delayed directional overcurrent elements will be allowed to operate, even with a three-phase voltage collapse.

1.25 Thermal Overload Protection

The relay incorporates a current based thermal replica, using rms load current to model heating and cooling of the protected plant. The element can be set with both alarm and trip stages.

The heat generated within an item of plant, such as a cable or a transformer, is the resistive loss (I2R x t). Thus, heating is directly proportional to current squared. The thermal time characteristic used in the relay is therefore based on current squared, integrated over time. The relay automatically uses the largest phase current for input to the thermal model.

Equipment is designed to operate continuously at a temperature corresponding to its full load rating, where heat generated is balanced with heat dissipated by radiation etc. Over-temperature conditions therefore occur when currents in excess of rating are allowed to flow for a period of time. It can be shown that temperatures during heating follow exponential time constants and a similar exponential decrease of temperature occurs during cooling.

The relay provides two characteristics that may be selected according to the application.

Thermal overload protection may be disabled by DDB 478 “**Inhibit Thermal >**“.

1.25.1 Single Time Constant Characteristic

This characteristic is used to protect cables, dry type transformers (e.g. type AN), and capacitor banks.

The thermal time characteristic is given by:

$$t = -\tau \log_e \left(\frac{I^2 - (K.I_{FLC})^2}{(I^2 - Ip^2)} \right)$$

Where:

t = Time to trip, following application of the overload current, I;
τ = Heating and cooling time constant of the protected plant;
I = Largest phase current;
IFLC = Full load current rating (relay setting ‘**Thermal Trip**’);
k = 1.05 constant, allows continuous operation up to <1.05 IFLC;
IP = Steady state pre-loading before application of the overload.

The time to trip varies depending on the load current carried before application of the overload, i.e. whether the overload was applied from '**hot**” or “**cold**”.

The thermal time constant characteristic may be rewritten as:

$$e^{(-t/\tau)} = \left(\frac{\theta - \theta_p}{\theta - 1} \right)$$

Where:

θ = I2/k2 IFLC2 and
θp = Ip2/k2 IFLC2

Where θ is the thermal state and is θp the pre-fault thermal state.

Note	*A current of 105%Is (kIFLC) has to be applied for several time constants to cause a thermal state measurement of 100%.*

1.25.2 Dual Time Constant Characteristic (typically not Applied for MiCOM P443/P446)

This characteristic is used to protect oil-filled transformers with natural air cooling (e.g. type ONAN). The thermal model is similar to that with the single time constant, except that two timer constants must be set.

For marginal overloading, heat will flow from the windings into the bulk of the insulating oil. Thus, at low current, the replica curve is dominated by the long time constant for the oil. This provides protection against a general rise in oil temperature.

For severe overloading, heat accumulates in the transformer windings, with little opportunity for dissipation into the surrounding insulating oil. Thus, at high current, the replica curve is dominated by the short time constant for the windings. This provides protection against hot spots developing within the transformer windings.

Overall, the dual time constant characteristic provided within the relay serves to protect the winding insulation from ageing, and to minimize gas production by overheated oil.

> *Note* *The thermal model does not compensate for the effects of ambient temperature change.*

The thermal curve is defined as:

$$0.4e^{(-t/\tau)} + 0.6e^{(-t/\tau)} = \frac{I^2 - (k.IFLC)^2}{I^2 - Ip^2}$$

Where:
τ1 = Heating and cooling time constant of the transformer windings;
τ2 = Heating and cooling time constant for the insulating oil.

In practice, it is difficult to solve this equation to give the operating time (t), therefore a graphical solution, using a spreadsheet package, is recommended. The spreadsheet can be arranged to calculate the current that will give a chosen operating time. The equation to calculate the current is defined as:

$$I = \sqrt{\frac{0.4Ip^2.e^{(-t/\tau 1)} + 0.6Ip^2.e^{(-t/\tau 2)} - k^2.I_{FLC}{}^2}{0.4\ e^{(-t/\tau 1)} + 0.6\ e^{(-t/\tau 2)} - 1}} \quad \text{…….. Equation 1}$$

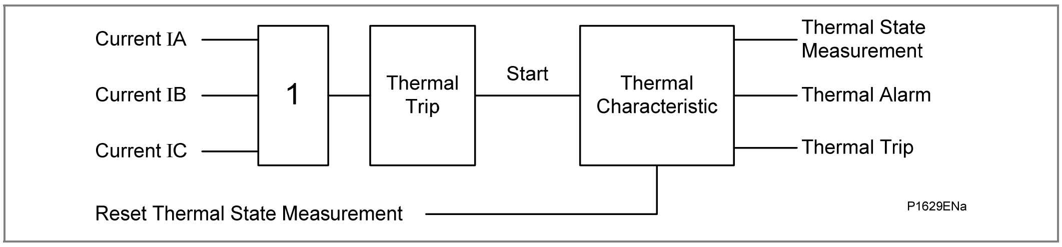


Figure 57 - Thermal overload protection logic diagram

The functional block diagram for the thermal overload protection is shown in Figure 57.

The magnitudes of the three phase input currents are compared and the largest magnitude taken as the input to the thermal overload function. If this current exceeds the thermal trip threshold setting a start condition is asserted.

1.26 Earth Fault (Ground Overcurrent), Sensitive Earth Fault (SEF) and Restricted Earth Fault (REF) Protection

The P443/P446 relay includes backup earth fault protection. Two elements are available; a derived earth fault element (where the residual current to operate the element is derived from the addition of the three line CT currents) and a sensitive earth fault element where low current settings are required. The sensitive earth fault element has a separate CT input and would normally be connected to a core balance CT. The derived and sensitive earth fault elements both have four stages of protection. The first two stages can be set either inverse time or definite time only. The third and fourth stages have a DT characteristic only. Each stage can be configured to be directional forward, directional reverse or non-directional.

Note	*The input CT which is designed specifically to operate at low current magnitudes is common to both the Sensitive Earth Fault (SEF) and high impedance Restricted Earth Fault (REF) protection, so these features are treated as mutually exclusive within the relay menu.*

Earth fault IN> protection (not applicable to SEF and REF Functions) is provided as a form of back-up protection that could be:

- Permanently disabled
- Permanently enabled
- Enabled only in case of VT fuse/MCB failure

In addition, each stage (not for SEF/REF) may be disabled by a DDB (467, 468, 469 and 470) “**Inhibit IN > x**“ (x = 1, 2, 3 or 4).

The VTS element of the relay can be selected to either block the directional element or simply remove the directional control.

The IN> and ISEF> Function Links settings have the following effect:

VTS Block - When the relevant is set to 1, operation of the Voltage Transformer Supervision (VTS) will block the stage if it directionalized. When set to 0 the stage will revert to non-directional upon operation of the VTS.

The inverse time characteristics available for the earth fault protection are the same as those for the phase overcurrent elements, but with the addition of an IDG curve characteristic.

Details of the IDG curve are provided as follows:

1.26.1 IDG Curve

The IDG curve is commonly used for time delayed earth fault protection in the Swedish market. This curve is available in stages 1 and 2 of Earth Fault and Sensitive Earth Fault protections.

The IDG curve is represented by the following equation:

$$t = 5.8 - 1.35 \log_e \left(\frac{I}{IN > Setting} \right) \text{ in seconds}$$

Where:

I = Measured current

IN>Setting = An adjustable setting which defines the start point of the characteristic

Although the start point of the characteristic is defined by the "**IN>**" setting, the actual relay current threshold is a different setting called "**IDG Is**". The "**IDG Is**" setting is set as a multiple of "**IN>**".

An additional setting "**IDG Time**" is also used to set the minimum operating time at high levels of fault current.

Figure 58 - illustrates how the IDG characteristic is implemented.

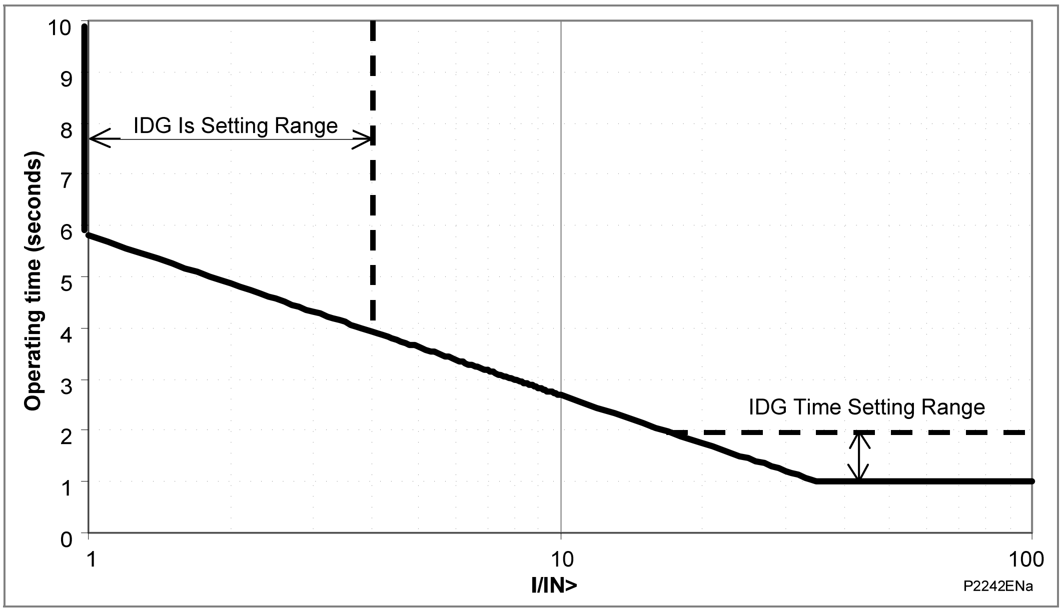


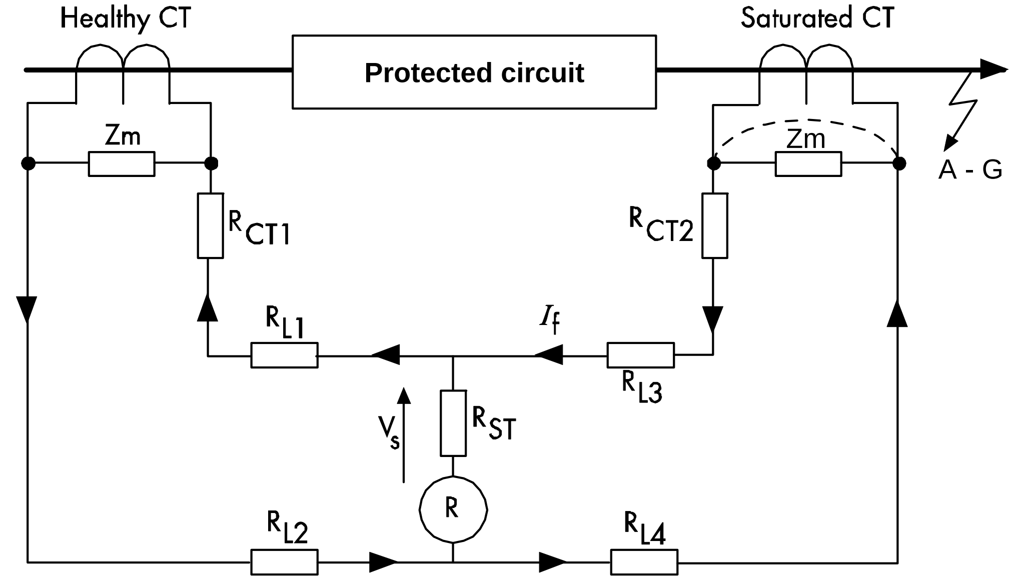
Figure 58 - IDG characteristic

1.26.2 Restricted Earth Fault protection (REF)

The REF protection in the P44y relays is a high impedance element which shares the same CT input as the SEF protection hence, only one of these elements may be selected.

The setting options are available under the **GROUP 1 SEF/REF PROT'N** menu.

The high impedance principle is best explained by considering a differential scheme where one CT is saturated for an external fault, as shown in Figure 59.



Voltage across relay circuit

$$V_s = I_f(R_{CT} + 2R_L)$$

Stabilising resistor, R_{ST}, limits spill current to I_s (relay setting)

$$R_{ST} = \frac{V_s}{I_s} - R_R$$

Where I_F = Maximum secondary through fault current

R_R = Relay burden

R_{CT} = Current transformer secondary winding resistance

R_L = Resistance of a single lead from the relay to the current transformer

P0115ENc

Figure 59 - High impedance principle

If the relay circuit is considered to be a very high impedance, the secondary current produced by the healthy CT will flow through the saturated CT. If CT magnetizing impedance of the saturated CT is considered to be negligible, the maximum voltage across the relay circuit will be equal to the secondary fault current multiplied by the connected impedance, (R_{L3} + R_{L4} + R_{CT2}).

The relay can be made stable for this maximum applied voltage by increasing the overall impedance of the relay circuit, such that the resulting current through the relay is less than its current setting. As the impedance of the relay input alone is relatively low, a series connected external resistor is required. The value of this resistor, R_{ST}, is calculated by the formula shown in Figure 59. An additional non-linear, metrosil, may be required to limit the peak secondary circuit voltage during internal fault conditions.

To ensure that the protection will operate quickly during an internal fault, the CT’s used to operate the protection must have a kneepoint voltage of at least 4 V s.

The necessary relay connections for high impedance REF are shown in Figure 60.

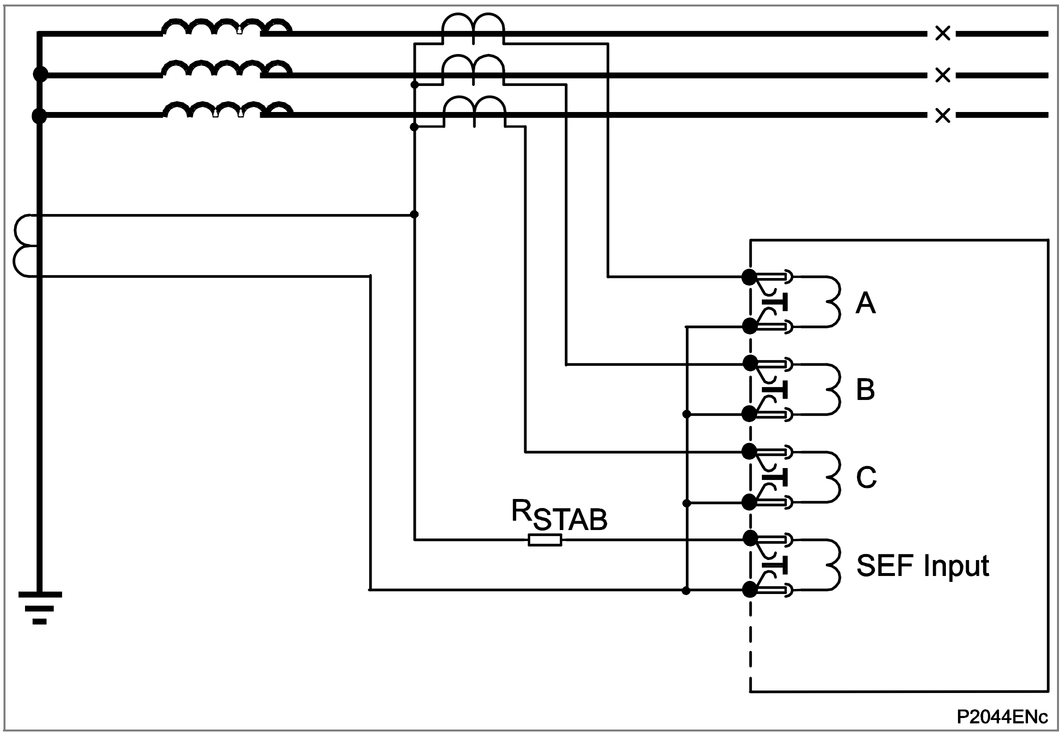


Figure 60 - High impedance REF relay/CT connections

1.27 Directional Earth Fault Protection

As stated in the previous sections, each of the four stages of earth fault protection may be set to directional if required. Consequently, as with the application of directional overcurrent protection, a suitable voltage supply is required by the relay to provide the necessary polarization. Two options are available for polarization; Residual Voltage or Negative Sequence.

1.28 Residual Voltage Polarization

With earth fault protection, the polarizing signal requires to be representative of the earth fault condition. As residual voltage is generated during earth fault conditions, this quantity is commonly used to polarize DEF elements. The relay internally derives this voltage from the 3 phase voltage input which must be supplied from either a 5-limb or three single phase VTs. These types of VT design allow the passage of residual flux and consequently permit the relay to derive the required residual voltage. In addition, the primary star point of the VT must be earthed. A three-limb VT has no path for residual flux and is therefore unsuitable to supply the relay.

Note	Residual voltage is nominally 180° out of phase with residual current. Consequently, the DEF relays are polarized from the '**-Vres**' quantity. This 180° phase shift is automatically introduced within the relay.

The directional criteria with zero sequence (residual voltage) polarization are given below:

Directional forward

$-90^{o} < (\text{angle(IN)} - \text{angle(VN}+180^{o}) - \text{RCA}) < 90^{o}$

Directional reverse

$-90^{o} > (\text{angle(IN)} - \text{angle(VN}+180^{o}) - \text{RCA}) > 90^{o}$

The *virtual current polarizing* feature is not available for use with the backup earth fault elements - that is used exclusively in DEF aided schemes only.

The logic diagram for directional earth fault overcurrent with neutral voltage polarization is shown in Figure 61.

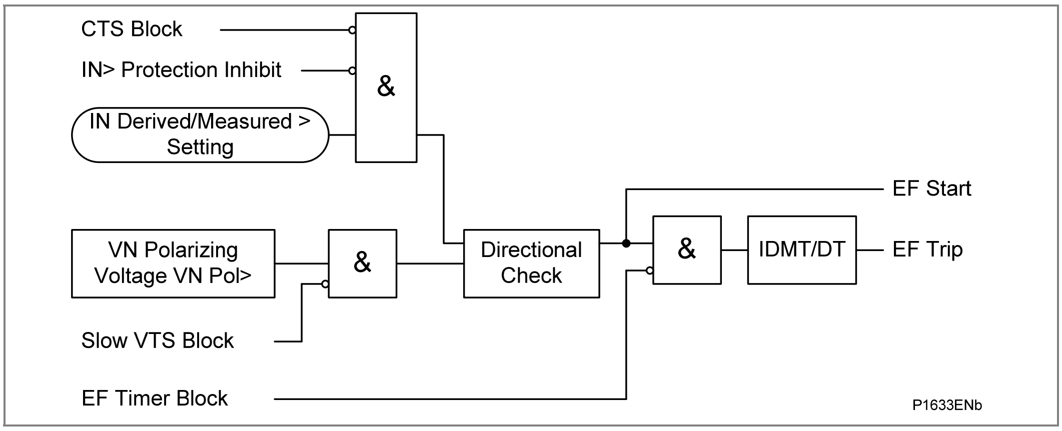


Figure 61 - Directional EF with neutral voltage polarization (single stage)

1.28.1 Negative Sequence Polarization (not for SEF)

In certain applications, the use of residual voltage polarization of DEF may either be not possible to achieve, or problematic. An example of the former case would be where a suitable type of VT was unavailable, for example if only a three limb VT was fitted. An example of the latter case would be an HV/EHV parallel line application where problems with zero sequence mutual coupling may exist.

In either of these situations, the problem may be solved by the use of negative phase sequence (nps) quantities for polarization. This method determines the fault direction by comparison of nps voltage with nps current. The operate quantity, however, is still residual current.

It requires a suitable voltage and current threshold to be set in cells "**IN>V2pol set**" and "**IN>I2pol set**", respectively.

Negative sequence polarizing is not recommended for impedance earthed systems regardless of the type of VT feeding the relay. This is due to the reduced earth fault current limiting the voltage drop across the negative sequence source impedance (V2pol) to negligible levels. If this voltage is less than 0.5 volts the relay will cease to provide DEF.

The logic diagram for directional earth fault overcurrent with negative sequence polarization is shown in Figure 62.

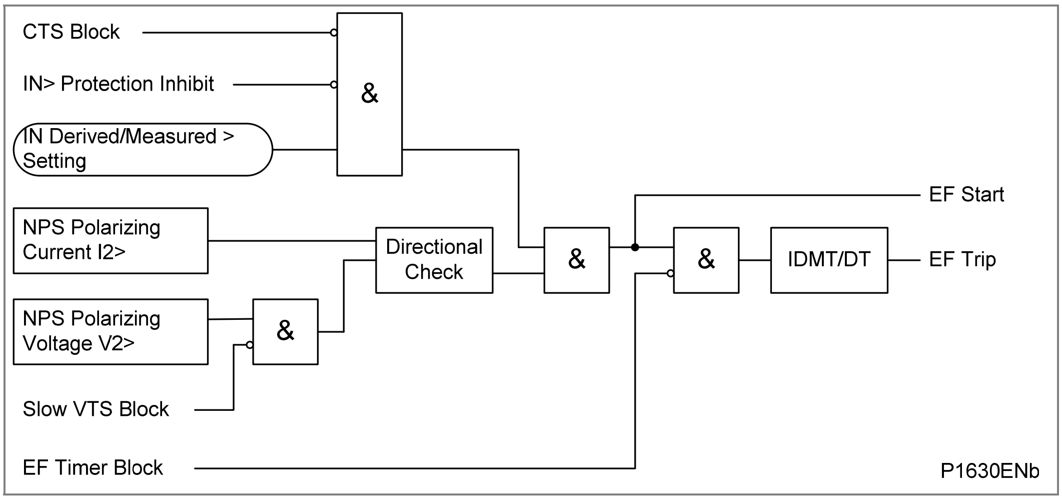

CTS Block
IN> Protection Inhibit
IN Derived/Measured > Setting
&
NPS Polarizing Current I2>
Directional Check
NPS Polarizing Voltage V2>
&
Slow VTS Block
EF Timer Block
&
&
IDMT/DT
EF Start
EF Trip
P1630ENb

Figure 62 - Directional EF with negative sequence polarization (single stage)

The directional criteria with negative sequence polarization is given below:

Directional forward

$-90° < (\text{angle}(I2) - \text{angle}(V2 + 180°) - RCA) < 90°$

Directional reverse

$-90° > (\text{angle}(I2) - \text{angle}(V2 + 180°) - RCA) > 90°$

1.29 Negative Sequence Overcurrent Protection (NPS)

The negative phase sequence overcurrent protection included in the P443/P446 relays provides four-stage non-directional/ directional overcurrent protection with independent time delay characteristics. The first two stages of overcurrent protection have time-delayed characteristics which are selectable between inverse definite minimum time (IDMT), or definite time (DT). The third and fourth stages have definite time characteristics only. The inverse time delayed characteristics support both IEC and IEEE curves and please refer to section 1.25 for a detailed description. The user may choose to directionalize operation of the elements, for either forward or reverse fault protection for which a suitable relay characteristic angle may be set. Alternatively, the elements may be set as non-directional.

For the negative phase sequence directional elements to operate, the relay must detect a polarizing voltage above a minimum threshold, "**I2> V2pol Set**". When the element is selected as directional, a VTS Block option is available. When the relevant bit is set to 1, operation of the Voltage Transformer Supervision (VTS), will block the stage if directionalized. When set to 0, the stage will revert to non-directional upon operation of the VTS.

When enabled, the following signals are set by the negative sequence O/C logic according to the status of the monitored function.

I2> Inhibit	(DDB 562)	Inhibit all 4 stages when high
I2>1 Tmr. Block	(DDB 563)	Block timer on 1st stage when high
I2>2 Tmr. Block	(DDB 564)	Block timer on 1st stage when high
I2>3 Tmr. Block	(DDB 565)	Block timer on 1st stage when high
I2>4 Tmr. Block	(DDB 566)	Block timer on 1st stage when high
I2>1 Start	(DDB 567)	1st stage started when high
I2>2 Start	(DDB 568)	2nd stage started when high
I2>3 Start	(DDB 569)	3rd stage started when high
I2>4 Start	(DDB 570)	4th stage started when high
I2>1 Trip	(DDB 571)	1st stage tripped when high
I2>2 Trip	(DDB 572)	2nd stage tripped when high
I3>3 Trip	(DDB 573)	3rd stage tripped when high
I4>4 Trip	(DDB 574)	4th stage tripped when high

All the above signals are available as DDB signals for mapping in Programmable Scheme Logic (PSL). In addition the negative sequence overcurrent protection trips 1/2/3/4 are mapped internally to the block auto-reclose logic.

Negative sequence overcurrent protection starts 1/2/3/4 are mapped internally to the ANY START DDB signal - DDB 736.

The non-directional and directional operation is shown in Figure 63 and Figure 64:

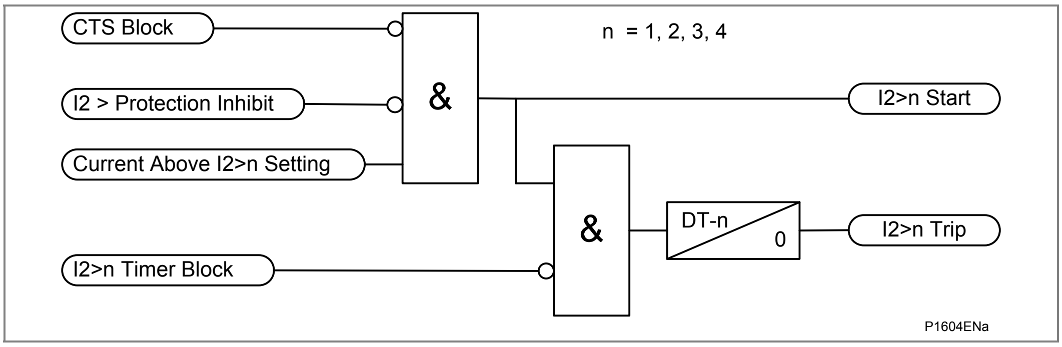

CTS Block
I2 > Protection Inhibit
Current Above I2>n Setting
I2>n Timer Block
&
&
n = 1, 2, 3, 4
DT-n
0
I2>n Start
I2>n Trip
P1604ENa

Figure 63 - Negative sequence overcurrent non-directional operation

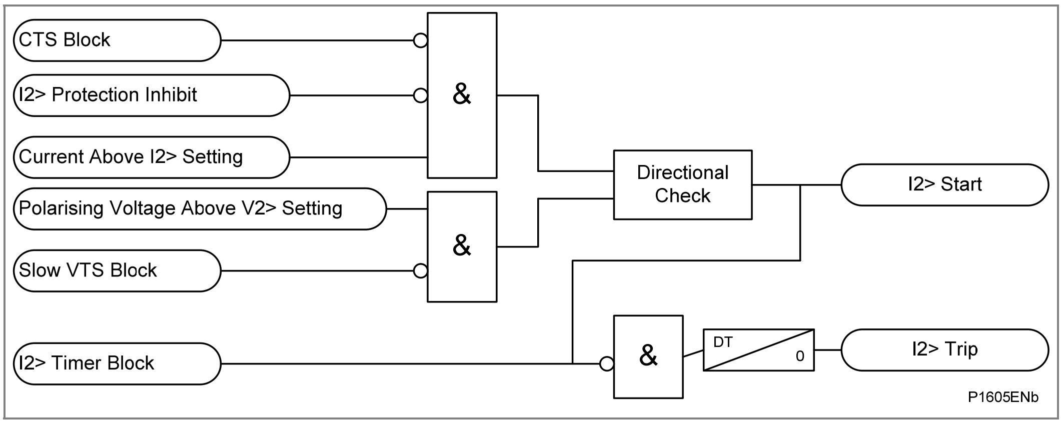

CTS Block
I2> Protection Inhibit
Current Above I2> Setting
Polarising Voltage Above V2> Setting
Slow VTS Block
I2> Timer Block
&
&
&
Directional Check
DT
0
I2> Start
I2> Trip
P1605ENb

Figure 64 - Directionalizing the negative phase sequence overcurrent element

1.29.1 Directionalizing the Negative Phase Sequence Overcurrent Element

Directionality is achieved by comparison of the angle between the negative phase sequence voltage and the negative phase sequence current and the element may be selected to operate in either the forward or reverse direction. A suitable relay characteristic angle setting (I2> Char Angle) is chosen to provide optimum performance. This setting should be set equal to the phase angle of the negative sequence current with respect to the inverted negative sequence voltage (– V2), in order to be at the center of the directional characteristic.

For the negative phase sequence directional elements to operate, the relay must detect a polarizing voltage above a minimum threshold, "**I2> V2pol Set**". The logic diagram for negative sequence overcurrent protection (shown with directional operation) is attached as Figure 65.

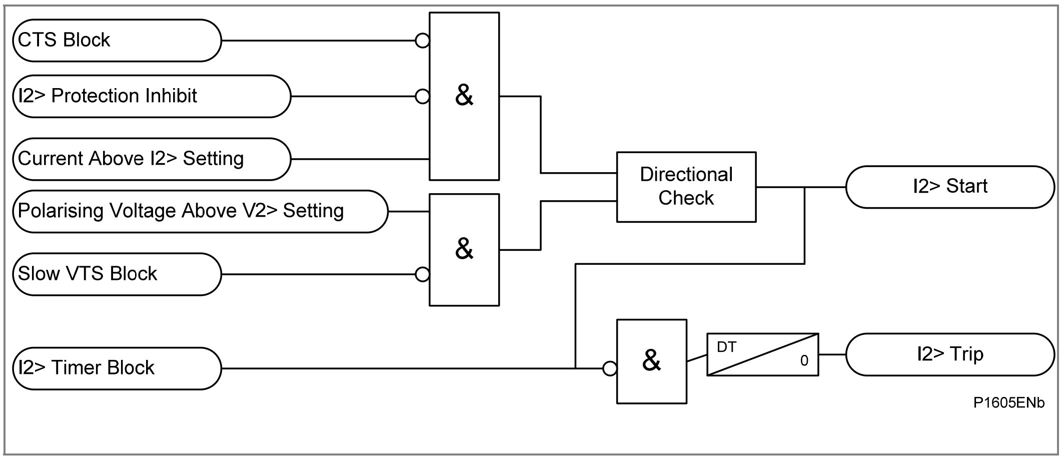


Figure 65 - Directionalizing the negative phase sequence overcurrent element

1.30 Undervoltage Protection

Both the under and overvoltage protection functions can be found in the relay menu "**Volt Protection**". The measuring mode (ph-N or ph-ph) and operating mode (single phase or 3 phase) for both stages are independently settable.

Stage 1 may be selected as either IDMT, DT or Disabled, within the "**V<1 function**" cell. Stage 2 is DT only and is enabled/disabled in the "**V<2 status**" cell.

Two stages are included to provide both alarm and trip stages, where required. Alternatively, different time settings may be required depending upon the severity of the voltage dip.

Outputs are available for single or three phase conditions via the "**V<Operate Mode**" cell.

When the protected feeder is de-energized, or the circuit breaker is opened, an undervoltage condition would be detected. Therefore, the "**V<Polehead Inh**" cell is included for each of the two stages to block the undervoltage protection from operating for this condition. If the cell is enabled, the relevant stage will become inhibited by the inbuilt pole dead logic within the relay. This logic produces an output when it detects either an open circuit breaker via auxiliary contacts feeding the relay opto inputs or it detects a combination of both undercurrent and undervoltage on any one phase.

The IDMT characteristic available on the first stage is defined by the following formula:

$t = K/(1 - M)$

Where:
K = Time multiplier setting
t = Operating time in seconds
M = Measured voltage/relay setting voltage (V< Voltage Set)

The logic diagram for the first stage undervoltage function is shown in Figure 66.

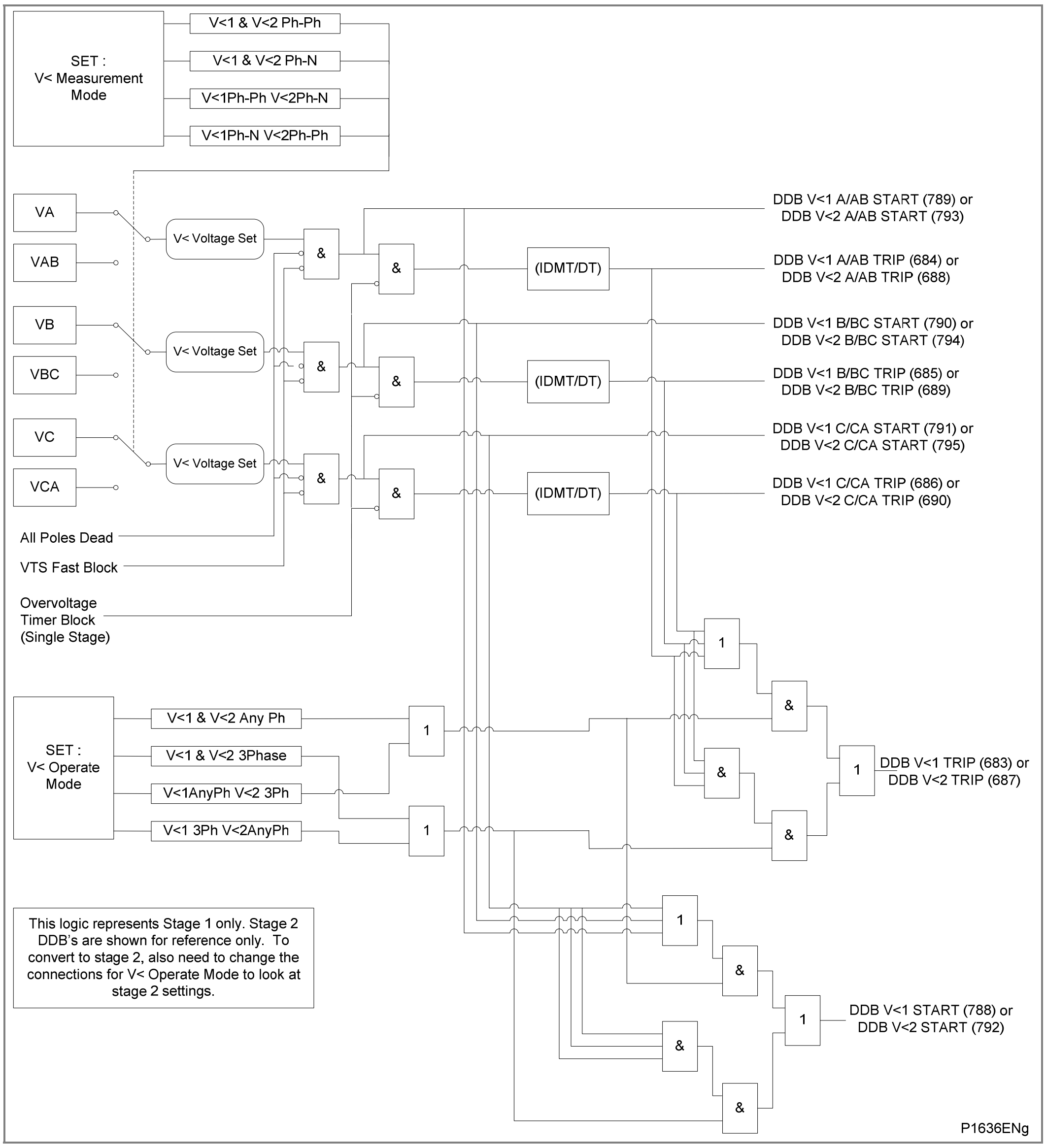

SET :
V< Measurement
Mode
V<1 & V<2 Ph-Ph
V<1 & V<2 Ph-N
V<1Ph-Ph V<2Ph-N
V<1Ph-N V<2Ph-Ph
VA
VAB
VB
VBC
VC
VCA
V< Voltage Set
V< Voltage Set
V< Voltage Set
&
&
(IDMT/DT)
DDB V<1 A/AB START (789) or DDB V<2 A/AB START (793)
DDB V<1 A/AB TRIP (684) or DDB V<2 A/AB TRIP (688)
DDB V<1 B/BC START (790) or DDB V<2 B/BC START (794)
DDB V<1 B/BC TRIP (685) or DDB V<2 B/BC TRIP (689)
DDB V<1 C/CA START (791) or DDB V<2 C/CA START (795)
DDB V<1 C/CA TRIP (686) or DDB V<2 C/CA TRIP (690)
All Poles Dead
VTS Fast Block
Overvoltage Timer Block (Single Stage)
SET :
V< Operate
Mode
V<1 & V<2 Any Ph
V<1 & V<2 3Phase
V<1AnyPh V<2 3Ph
V<1 3Ph V<2AnyPh
1
DDB V<1 TRIP (683) or DDB V<2 TRIP (687)
DDB V<1 START (788) or DDB V<2 START (792)
This logic represents Stage 1 only. Stage 2 DDB's are shown for reference only. To convert to stage 2, also need to change the connections for V< Operate Mode to look at stage 2 settings.
P1636ENg

Figure 66 - Undervoltage - single and three phase tripping mode (single stage)

It should be noted that undervoltage protection is phase segregated, but the operation of any phase is mapped to 3 phase tripping in the default PSL.

Each stage of Undervoltage protection may be disabled by a DDB (471 or 472) “**Inhibit Vx<**“.

1.31 Overvoltage Protection

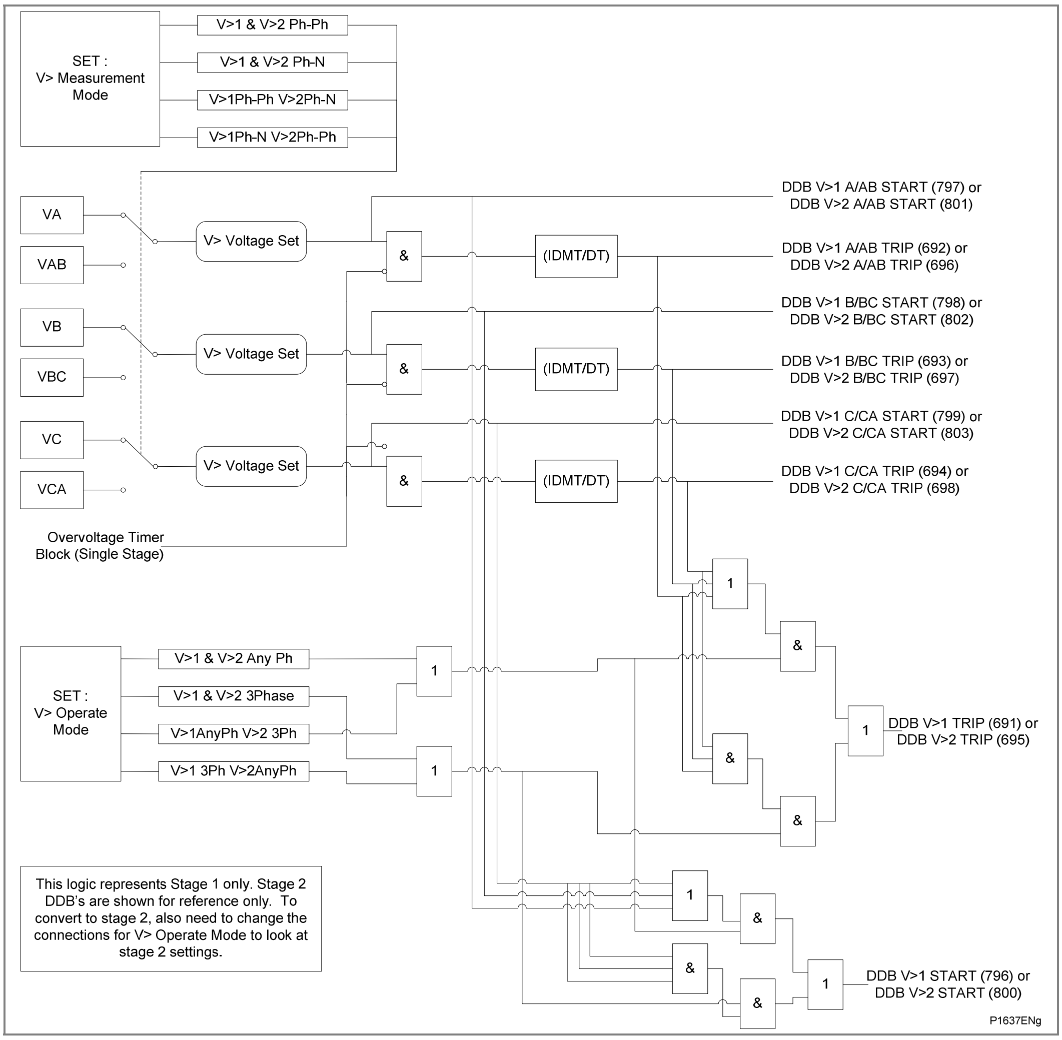
Both the over and undervoltage protection functions can be found in the relay menu "**Volt Protection**". The measuring mode (ph-N or ph-ph) and operating mode (single phase or 3 phase) for both stages are independently settable.

The IDMT characteristic available on the first stage is defined by the following formula:

$t = K/(M - 1)$

Where:
K = Time multiplier setting
t = Operating time in seconds
M = Measured voltage/relay setting voltage (V> Voltage Set)

The logic diagram for the first stage overvoltage function is shown in Figure 67.



SET : V> Measurement Mode
V>1 & V>2 Ph-Ph
V>1 & V>2 Ph-N
V>1Ph-Ph V>2Ph-N
V>1Ph-N V>2Ph-Ph
VA
VAB
VB
VBC
VC
VCA
V> Voltage Set
V> Voltage Set
V> Voltage Set
&
&
&
(IDMT/DT)
(IDMT/DT)
(IDMT/DT)
DDB V>1 A/AB START (797) or DDB V>2 A/AB START (801)
DDB V>1 A/AB TRIP (692) or DDB V>2 A/AB TRIP (696)
DDB V>1 B/BC START (798) or DDB V>2 B/BC START (802)
DDB V>1 B/BC TRIP (693) or DDB V>2 B/BC TRIP (697)
DDB V>1 C/CA START (799) or DDB V>2 C/CA START (803)
DDB V>1 C/CA TRIP (694) or DDB V>2 C/CA TRIP (698)
Overvoltage Timer Block (Single Stage)
SET : V> Operate Mode
V>1 & V>2 Any Ph
V>1 & V>2 3Phase
V>1AnyPh V>2 3Ph
V>1 3Ph V>2AnyPh
1
1
1
&
&
&
1
DDB V>1 TRIP (691) or DDB V>2 TRIP (695)
1
&
&
&
1
DDB V>1 START (796) or DDB V>2 START (800)
P1637ENg

This logic represents Stage 1 only. Stage 2 DDB's are shown for reference only. To convert to stage 2, also need to change the connections for V> Operate Mode to look at stage 2 settings.

Figure 67 - Overvoltage - single and three phase tripping mode (single stage)

It should be noted that phase overvoltage protection is phase segregated, but the operation of any phase is mapped to 3 phase tripping in the default PSL.

Each stage of Overvoltage protection may be disabled by a DDB (473 or 474) "**Inhibit Vx>**" (x = 1, 2).

1.31.1 Compensated Overvoltage

The Compensated Overvoltage function calculates the positive sequence voltage at the remote terminal using the positive sequence local current and voltage and the line impedance and susceptance. This can be used on long transmission lines where Ferranti Overvoltages can develop under remote circuit breaker open conditions.

The Compensated overvoltage protection function can be found in the relay menu "**Volt Protection**". The line impedance settings together with the line charging admittance in relay menu “**Line Parameters**” is used to calculate the remote voltage.

The relay uses the {A, B, C, D] transmission line equivalent model given the following parameters:

Total Impedance $Z = z\angle\theta\Omega$ and
Total Susceptance $Y = y\angle -90\Omega$ and
Line Length l

The remote voltage is calculated using the following equations:

$$\begin{bmatrix} \bar{Vr} \\ \bar{Ir} \end{bmatrix} = \begin{bmatrix} D & -C \\ -B & A \end{bmatrix} \times \begin{bmatrix} \bar{Vs} \\ \bar{Is} \end{bmatrix}$$

Where:

Vr, Ir	-	Voltage and Current at the receiving end.
Vs, Is	-	Measured (relay) Voltage and Current at the sending end.

$$A = D = \cosh(\gamma \times l)$$
$$B = Zc \times \sinh(\gamma \times l)$$
$$C = Yc \times \sinh(\gamma \times l)$$
$$\gamma \times l = \sqrt{ZY}$$
$$Zc = \frac{1}{Yc} = \sqrt{\frac{Z}{Y}}$$

Y - Total Line Capacitive Charging Susceptance
Zc = Characteristic Impedance of the line (Surge Impedance).

Two stages are included to provide both alarm and trip stages, where required.

Both stages are independently settable where Stage 1 may be selected as either IDMT, DT or Disabled, within the "**V1>1 Cmp Funct**" cell. Stage 2 is DT only and is enabled/disabled in the "**V1>Cmp Status**" cell.

The IDMT characteristic available on the first stage is defined by the following formula:

t = K/(M - 1)

Where:
K = Time multiplier setting
t = Operating time in seconds
M = Remote Calculated voltage/relay setting voltage (PH-)

1.32 Residual Overvoltage (Neutral Displacement) Protection

The NVD element within The MiCOM P443/P446 is of two stage design, each stage having separate voltage and time delay settings. Stage 1 may be set to operate on either an IDMT or DT characteristic, whilst stage 2 may be set to DT only. Two stages are included for the NVD protection to account for applications which require both alarm and trip stages.

The relay internally derives the NVD voltage from the 3 input phases which must be supplied from either a 5-limb or three single phase VTs. These types of VT design allow the passage of residual flux and consequently permit the relay to derive the required residual voltage. In addition, the primary star point of the VT must be earthed. A three limb VT has no path for residual flux and is therefore unsuitable to supply the relay.

The IDMT characteristic available on the first stage is defined by the following formula:

$t = K/(M - 1)$

Where:
K = Time multiplier setting
t = Operating time in seconds
M = Derived residual voltage/relay setting voltage (VN> Voltage Set)

The functional block diagram of the first stage residual overvoltage is shown in Figure 68:

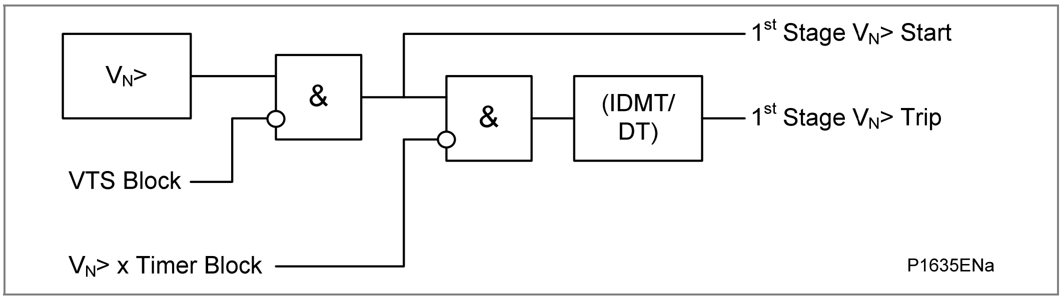


Figure 68 - Residual overvoltage logic (single stage)

Each stage of Residual Overvoltage protection may be disabled by a DDB (475 or 476) “**Inhibit VN>x**“ (x = 1, 2).

1.33 Circuit Breaker Fail (CBF) Protection

The CBF protection incorporates two timers, CB Fail 1 Timer and CB Fail 2 Timer, allowing configuration for the following scenarios:

- Simple CBF, where only CB Fail 1 Timer is enabled. For any protection trip, the CB Fail 1 Timer is started, and normally reset when the circuit breaker opens to isolate the fault. If breaker opening is not detected, CB Fail 1 Timer times out and closes an output contact assigned to breaker fail (using the programmable scheme logic). This contact is used to backtrip upstream switchgear, generally tripping all infeeds connected to the same busbar section.
- A re-tripping scheme, plus delayed backtripping. Here, CB Fail 1 Timer is used to route a trip to a second trip circuit of the same circuit breaker. This requires duplicated circuit breaker trip coils, and is known as re-tripping. Should re-tripping fail to open the circuit breaker, a backtrip may be issued following an additional time delay. The backtrip uses CB Fail 2 Timer, which is also started at the instant of the initial protection element trip. CBF elements CB Fail 1 Timer and CB Fail 2 Timer can be configured to operate for trips triggered by protection elements within the relay or via an external protection trip. The latter is achieved by allocating one of the relay opto-isolated inputs to External Trip using the programmable scheme logic.

In the existing designs, the fast undercurrent is used to determine if the circuit breaker has opened. This can take up to 160ms to reset under some fault conditions - for example, where the current resembles a slow decaying dc component after the circuit breaker has opened to clear the fault current. For example see Figure 69.

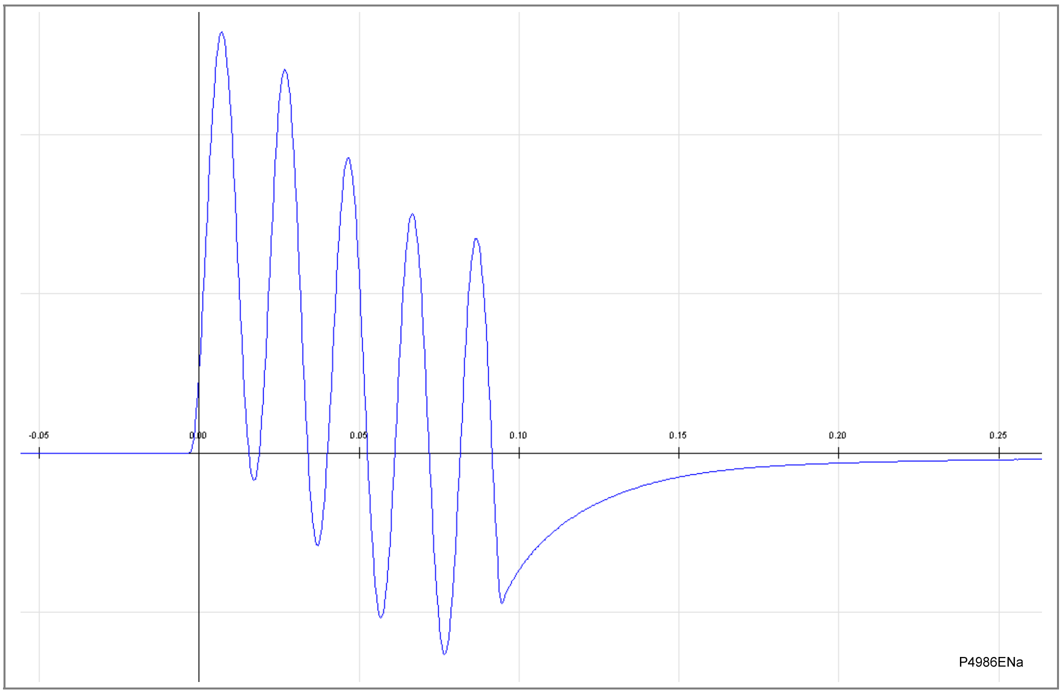


Figure 69 - Decaying dc component

The length of the operating time is primarily related to the usage of the combination of Fourier magnitudes and the 3-sample interpolation method used for the undercurrent reset algorithm. In some applications, a 160ms reset time is too slow.

In this software release, we have introduced a Zero Cross Detector (ZCD) to shorten the reset time. In some cases, it is preferable to record measured sample values of a variable waveform. However, we have found it acceptable to record the magnitude of the waveform. For example, see Figure 70.

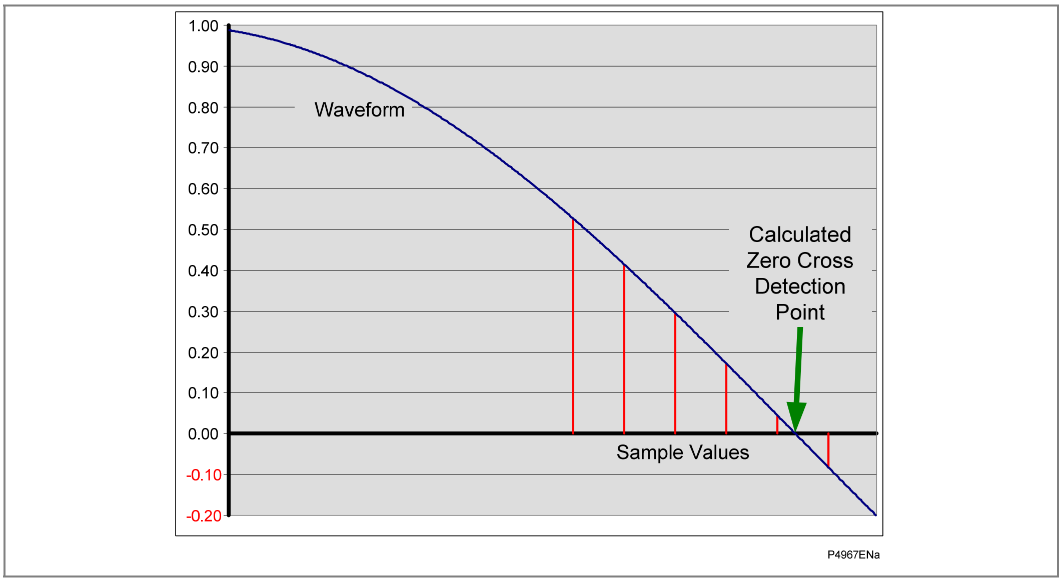


Figure 70 - Calculating a Zero Cross Detection Point using sample values

We have modified the CB Fail logic to incorporate the addition of ZCD signals with a time delayed drop off of 1/2 a cycle for each phase current and the SEF current. These are logically combined with the output of the breaker fail timers to determine breaker fail trip operation.

The objective of this software release is to improve the reset performance of the CB Fail. The target reset time is ¾ cycle (i.e. 15ms for a 50Hz signal).

The CBF timer settings have the same setting range as the existing design but the step size has been reduced from 10ms to 1ms.

1.33.1 Reset Mechanisms for Breaker Fail Timers

It is common practice to use low set undercurrent elements in protection relays to indicate that circuit breaker poles have interrupted the fault or load current, as required. This covers the following situations:

- Where circuit breaker auxiliary contacts are defective, or cannot be relied upon to definitely indicate that the breaker has tripped.
- Where a circuit breaker has started to open but has become jammed. This may result in continued arcing at the primary contacts, with an additional arcing resistance in the fault current path. Should this resistance severely limit fault current, the initiating protection element may reset. Therefore, reset of the element may not give a reliable indication that the circuit breaker has opened fully.

For any protection function requiring current to operate, the relay uses operation of undercurrent elements (I<) to detect that the necessary circuit breaker poles have tripped and reset the CB fail timers. However, the undercurrent elements may not be reliable methods of resetting circuit breaker fail in all applications. For example:

- Where non-current operated protection, such as under/overvoltage derives measurements from a line connected voltage transformer. Here, I< only gives a reliable reset method if the protected circuit would always have load current flowing. Detecting drop-off of the initiating protection element might be a more reliable method.
- Similarly, where the distance scheme includes Weak Infeed (“WI”) trip logic, the reset of the WI trip condition should be used in addition to the undercurrent check. Set: ***WI Prot Rese’*** = Enabled.

- Where non-current operated protection, such as under/overvoltage derives measurements from a busbar connected voltage transformer. Again using I< would rely upon the feeder normally being loaded. Also, tripping the circuit breaker may not remove the initiating condition from the busbar, and hence drop-off of the protection element may not occur. In such cases, the position of the circuit breaker auxiliary contacts may give the best reset method.

Resetting of the CBF is possible from a breaker open indication (from the relay's pole dead logic) or from a protection reset. In these cases, resetting is only allowed provided the undercurrent elements have also reset. The resetting options are summarized in Table 15.

Initiation (menu selectable)	CB fail timer reset mechanism
Current based protection (e.g. 50/51/46/21/67)	The resetting mechanism is fixed [IA< operates] & [IB< operates] & [IC< operates] & [IN< operates]
Non-current based protection (e.g. 27/59)	Three options are available. The user can Select from the following options: [All I< and IN< elements operate] [Protection element reset] AND [All I< and N< elements operate] CB open (all 3 poles) AND [All I< and IN< elements operate]
External protection	Three options are available: The user can select any or all of the options. [All I< and IN< elements operate] [External trip reset] AND [All I< and IN< elements operate] CB open (all 3 poles) AND [All I< and IN< elements operate]

Table 15 - Initiation (menu selectable) and CB fail timer reset mechanism

The complete breaker fail logic is shown in Figure 71, Figure 72 and Figure 73.

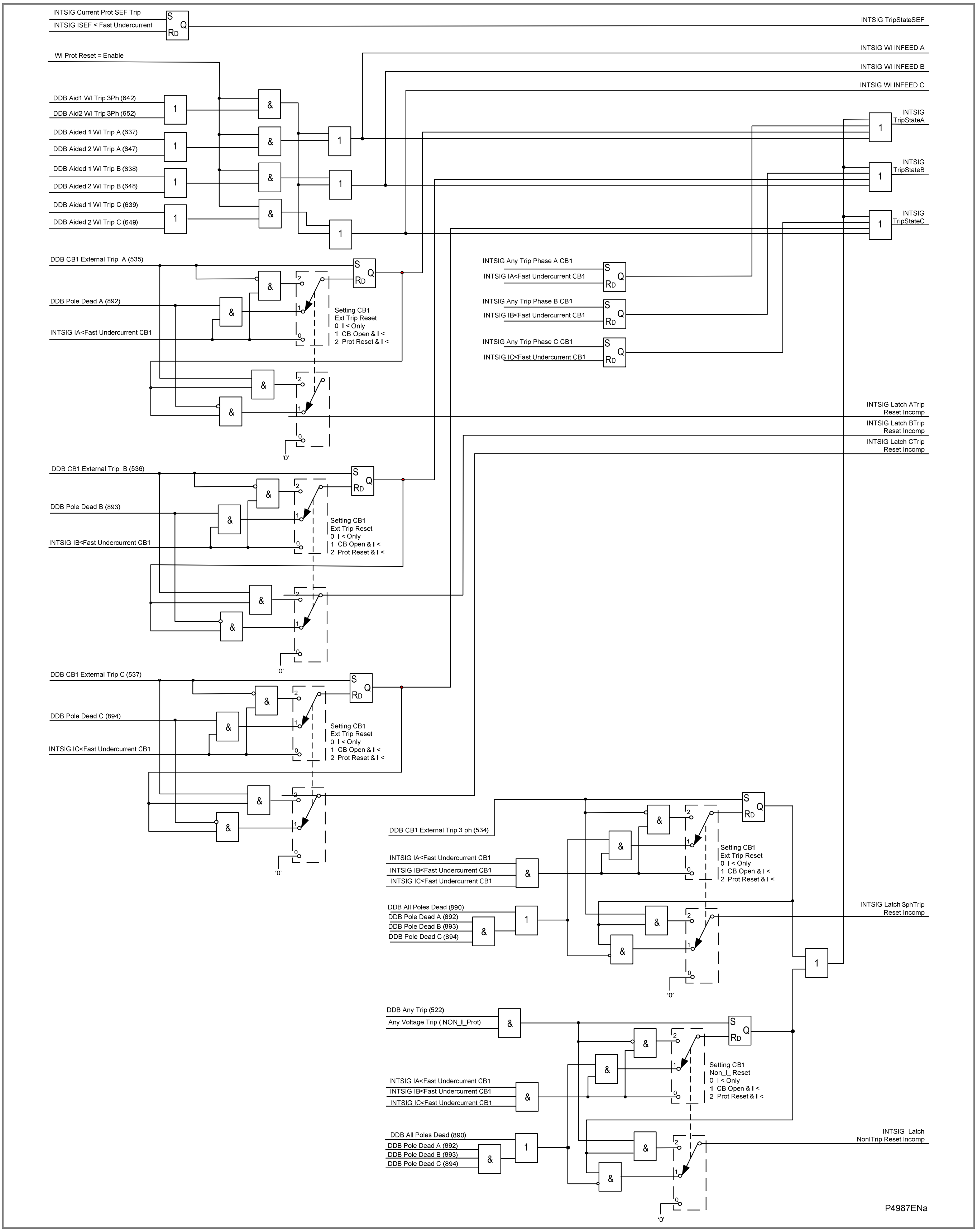

INTSIG Current Prot SEF Trip
INTSIG ISEF < Fast Undercurrent
S
Q
RD
INTSIG TripStateSEF
WI Prot Reset = Enable
INTSIG WI INFEED A
INTSIG WI INFEED B
INTSIG WI INFEED C
DDB Aid1 WI Trip 3Ph (642)
DDB Aid2 WI Trip 3Ph (652)
DDB Aided 1 WI Trip A (637)
DDB Aided 2 WI Trip A (647)
DDB Aided 1 WI Trip B (638)
DDB Aided 2 WI Trip B (648)
DDB Aided 1 WI Trip C (639)
DDB Aided 2 WI Trip C (649)
1
&
INTSIG TripStateA
INTSIG TripStateB
INTSIG TripStateC
DDB CB1 External Trip A (535)
DDB Pole Dead A (892)
INTSIG IA<Fast Undercurrent CB1
Setting CB1 Ext Trip Reset
0 I < Only
1 CB Open & I <
2 Prot Reset & I <
'0'
INTSIG Any Trip Phase A CB1
INTSIG IA<Fast Undercurrent CB1
INTSIG Any Trip Phase B CB1
INTSIG IB<Fast Undercurrent CB1
INTSIG Any Trip Phase C CB1
INTSIG IC<Fast Undercurrent CB1
INTSIG Latch ATrip Reset Incomp
INTSIG Latch BTrip Reset Incomp
INTSIG Latch CTrip Reset Incomp
DDB CB1 External Trip B (536)
DDB Pole Dead B (893)
INTSIG IB<Fast Undercurrent CB1
DDB CB1 External Trip C (537)
DDB Pole Dead C (894)
INTSIG IC<Fast Undercurrent CB1
DDB CB1 External Trip 3 ph (534)
INTSIG IA<Fast Undercurrent CB1
INTSIG IB<Fast Undercurrent CB1
INTSIG IC<Fast Undercurrent CB1
DDB All Poles Dead (890)
DDB Pole Dead A (892)
DDB Pole Dead B (893)
DDB Pole Dead C (894)
INTSIG Latch 3phTrip Reset Incomp
DDB Any Trip (522)
Any Voltage Trip (NON_I_Prot)
Setting CB1 Non_I_ Reset
0 I < Only
1 CB Open & I <
2 Prot Reset & I <
INTSIG Latch NonITrip Reset Incomp
P4987ENa

Figure 71 - CB1 failure logic - Part 1 of 2 (for MiCOM P443 and P446)

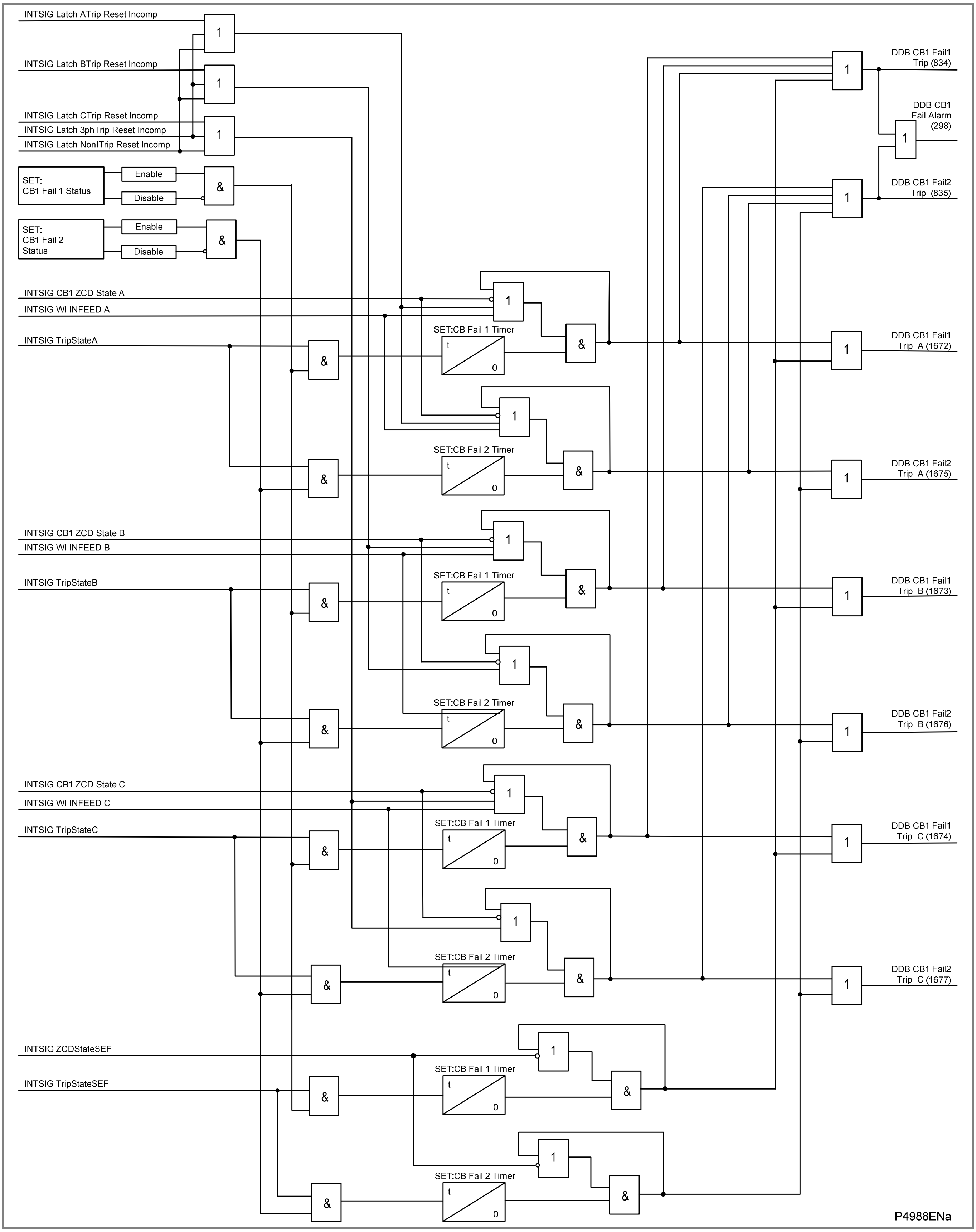

INTSIG Latch ATrip Reset Incomp
INTSIG Latch BTrip Reset Incomp
INTSIG Latch CTrip Reset Incomp
INTSIG Latch 3phTrip Reset Incomp
INTSIG Latch NonITrip Reset Incomp
SET:
CB1 Fail 1 Status
Enable
Disable
SET:
CB1 Fail 2
Status
Enable
Disable
INTSIG CB1 ZCD State A
INTSIG WI INFEED A
INTSIG TripStateA
INTSIG CB1 ZCD State B
INTSIG WI INFEED B
INTSIG TripStateB
INTSIG CB1 ZCD State C
INTSIG WI INFEED C
INTSIG TripStateC
INTSIG ZCDStateSEF
INTSIG TripStateSEF
SET:CB Fail 1 Timer
SET:CB Fail 2 Timer
t
0
1
&
DDB CB1 Fail1
Trip (834)
DDB CB1
Fail Alarm
(298)
DDB CB1 Fail2
Trip (835)
DDB CB1 Fail1
Trip A (1672)
DDB CB1 Fail2
Trip A (1675)
DDB CB1 Fail1
Trip B (1673)
DDB CB1 Fail2
Trip B (1676)
DDB CB1 Fail1
Trip C (1674)
DDB CB1 Fail2
Trip C (1677)
P4988ENa

Figure 72 - CB1 failure logic - Part 2 of 2 (for MiCOM P443 and P446)

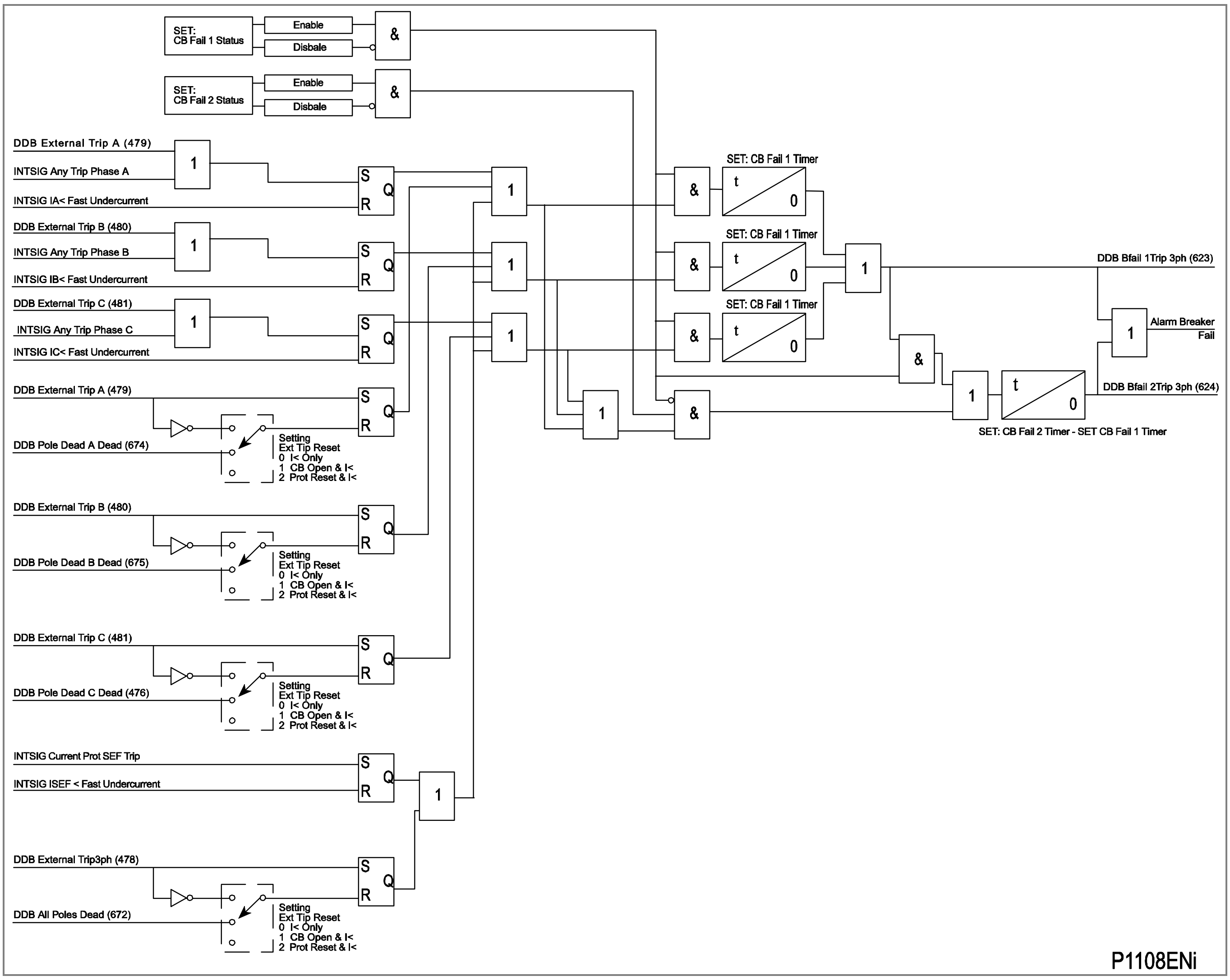

SET: CB Fail 1 Status
Enable
Disbale
SET: CB Fail 2 Status
Enable
Disbale
DDB External Trip A (479)
INTSIG Any Trip Phase A
INTSIG IA< Fast Undercurrent
DDB External Trip B (480)
INTSIG Any Trip Phase B
INTSIG IB< Fast Undercurrent
DDB External Trip C (481)
INTSIG Any Trip Phase C
INTSIG IC< Fast Undercurrent
DDB External Trip A (479)
DDB Pole Dead A Dead (674)
DDB External Trip B (480)
DDB Pole Dead B Dead (675)
DDB External Trip C (481)
DDB Pole Dead C Dead (476)
Setting
Ext Tip Reset
0 I< Only
1 CB Open & I<
2 Prot Reset & I<
INTSIG Current Prot SEF Trip
INTSIG ISEF < Fast Undercurrent
DDB External Trip3ph (478)
DDB All Poles Dead (672)
SET: CB Fail 1 Timer
SET: CB Fail 1 Timer
SET: CB Fail 1 Timer
DDB Bfail 1Trip 3ph (623)
Alarm Breaker Fail
DDB Bfail 2Trip 3ph (624)
SET: CB Fail 2 Timer - SET CB Fail 1 Timer
P1108ENi

Figure 73 - CB2 failure (for MiCOM P446)

1.34 Broken Conductor Detection

The relay incorporates an element which measures the ratio of negative to positive phase sequence current (I2/I1). This will be affected to a lesser extent than the measurement of negative sequence current alone, since the ratio is approximately constant with variations in load current. Hence, a more sensitive setting may be achieved.

The logic diagram is as shown below. The ratio of I2/I1 is calculated and is compared with the threshold and if the threshold is exceeded then the delay timer is initiated. The CTS block signal is used to block the operation of the delay timer.

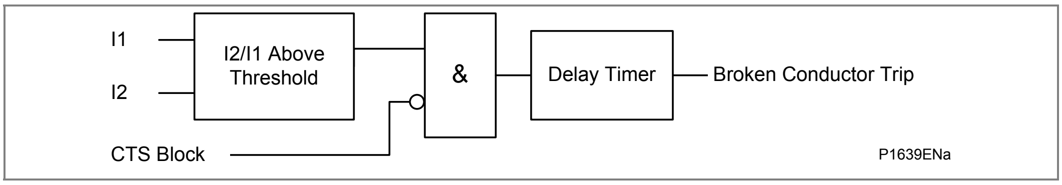

I1
I2
I2/I1 Above Threshold
&
Delay Timer
Broken Conductor Trip
CTS Block
P1639ENa

Figure 74 - Broken conductor logic

1.35 Frequency Protection

The relay includes 4 stages of underfrequency and 2 stages of overfrequency protection to facilitate load shedding and subsequent restoration. The underfrequency stages may be optionally blocked by an undervoltage level (setting CB FAIL & P.DEAD/POLEDEAD VOLTAGE/V<). All the stages may be enabled/disabled in the "**F<n Status**" or "**F>n Status**" cell depending on which element is selected.

The logic diagram for the underfrequency logic is as shown in Figure 76. Only a single stage is shown. The other 3 stages are identical in functionality.

If the frequency is below the setting and not blocked the DT timer is started. Blocking may come from the Undervoltage level (selectively enabled for each stage) or the underfrequency timer block.

If the frequency cannot be determined, the function is also blocked.

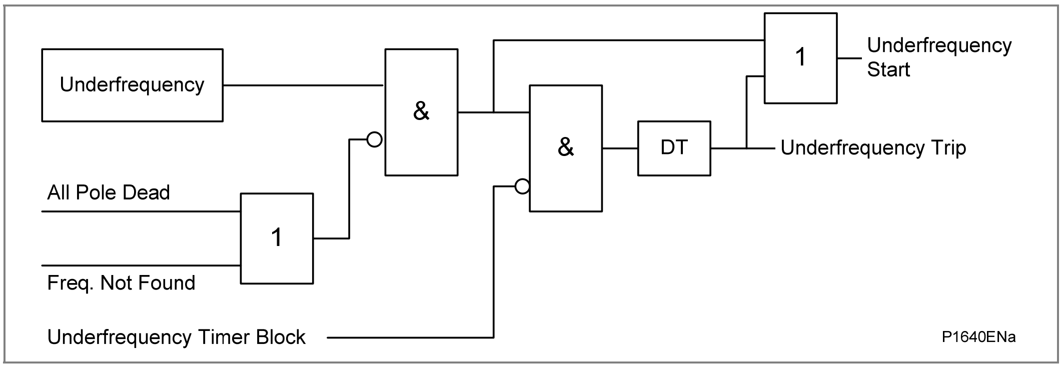

Underfrequency
&
1
Underfrequency Start
&
DT
Underfrequency Trip
All Pole Dead
1
Freq. Not Found
Underfrequency Timer Block
P1640ENa

Figure 75 - Underfrequency logic (single stage)

The functional logic diagram is for the overfrequency function as shown in Figure 77. Only a single stage is shown as the other stages are identical in functionality. If the frequency is above the setting and not blocked the DT timer is started and after this has timed out the trip is produced. Blocking may come from the All_Poledead signal (selectively enabled for each stage) or the overfrequency timer block.

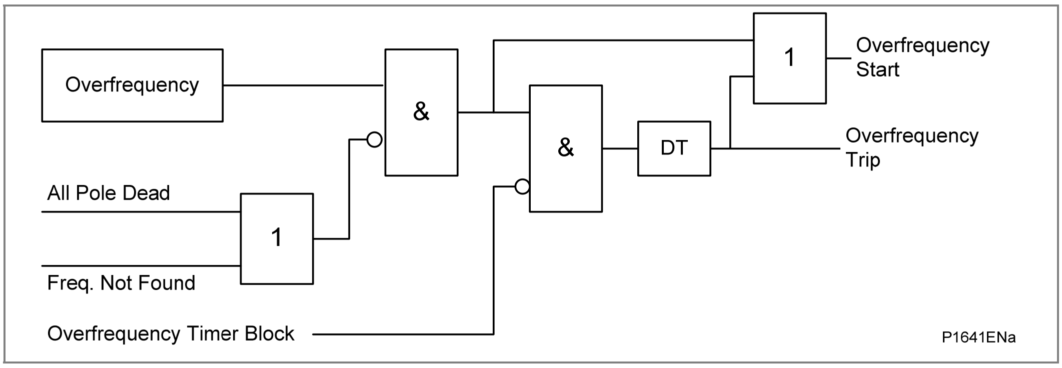

Overfrequency
&
1
Overfrequency Start
&
DT
Overfrequency Trip
All Pole Dead
1
Freq. Not Found
Overfrequency Timer Block
P1641ENa

Figure 76 - Overfrequency logic (single stage)

When enabled, the following signals are set by the under/overfrequency logic according to the status of the monitored functions.

F<1 Timer Block	(DDB 1149)	Block Underfrequency Stage 1 Timer
F<2 Timer Block	(DDB 1150)	Block Underfrequency Stage 2 Timer
F<3 Timer Block	(DDB 1151)	Block Underfrequency Stage 3 Timer
F<4 Timer Block	(DDB 1152)	Block Underfrequency Stage 4 Timer
F>1 Timer Block	(DDB 1153)	Block Overfrequency Stage 1 Timer
F>2 Timer Block	(DDB 1154)	Block Overfrequency Stage 2 Timer
F<1 Start	(DDB 1155)	Underfrequency Stage 1 Start
F<2 Start	(DDB 1156)	Underfrequency Stage 2 Start
F<3 Start	(DDB 1157)	Underfrequency Stage 3 Start
F<4 Start	(DDB 1158)	Underfrequency Stage 4 Start
F>1 Start	(DDB 1159)	Overfrequency Stage 1 Start
F>2 Start	(DDB 1160)	Overfrequency Stage 2 Start
F<1 Trip	(DDB 1161)	Underfrequency Stage 1 Trip
F<2 Trip	(DDB 1162)	Underfrequency Stage 2 Trip
F<3 Trip	(DDB 1163)	Underfrequency Stage 3 Trip
F<4 Trip	(DDB 1164)	Underfrequency Stage 4 Trip
F>1 Trip	(DDB 1165)	Overfrequency Stage 1 Trip
F>2 Trip	(DDB 1166)	Overfrequency Stage 2 Trip
Inhibit F<1	(DDB 1167)	Inhibit stage 1 Under frequency protection
Inhibit F<2	(DDB 1168)	Inhibit stage 2 Under frequency protection
Inhibit F<3	(DDB 1169)	Inhibit stage 3 Under frequency protection
Inhibit F<4	(DDB 1170)	Inhibit stage 4 Under frequency protection
Inhibit F>1	(DDB 1171)	Inhibit stage 1 Over frequency protection
Inhibit F>2	(DDB 1172)	Inhibit stage 2 Over frequency protection

1.36 Independent Rate of Change of Frequency Protection [81R]

In the load shedding scheme below, it is assumed under falling frequency conditions that by shedding a stage of load, the system can be stabilized at frequency f2. For slow rates of decay, this can be achieved using the underfrequency protection element set at frequency f1 with a suitable time delay. However, if the generation deficit is substantial, the frequency will rapidly decrease and it is possible that the time delay imposed by the underfrequency protection will not allow for frequency stabilization. In this case, the chance of system recovery will be enhanced by disconnecting the load stage based upon a measurement of rate of change of frequency and bypassing the time delay.

This element is a rate of change of frequency monitoring element, and operates independently from the under and over frequency protection functions. A timer is included to provide a time delayed operation and the element can be utilized to provide extra flexibility to a load shedding scheme in dealing with severe load to generation imbalances.

Since the rate of change monitoring is independent of frequency, the element can identify frequency variations occurring close to nominal frequency and thus provide early warning to the operator on a developing frequency problem. Additionally, the element could also be used as an alarm to warn operators of unusually high system frequency variations.

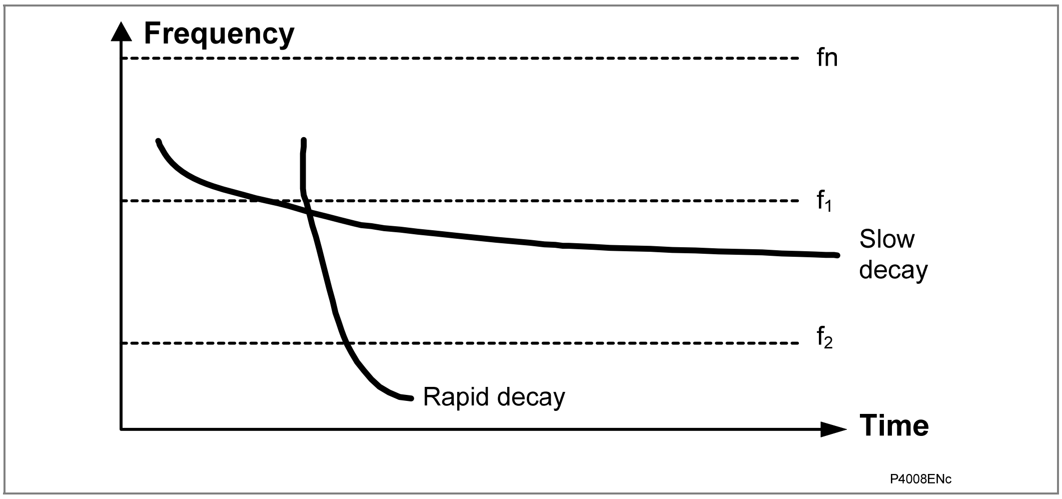


Figure 77 - Rate of change of frequency protection

1.36.1 Basic Functionality

The relay provides four independent stages of rate of change of frequency protection (df/dt+t). Depending upon whether the rate of change of frequency setting is set positive or negative, the element will react to rising or falling frequency conditions respectively, with an incorrect setting being indicated if the threshold is set to zero. The output of the element would normally be given a user-selectable time delay, although it is possible to set this to zero and create an instantaneous element.

An Independent setting is available for calculating the rate of change of frequency measurement, "**df/dt Avg. Cycles**" over a fixed period of either 6 or 12 cycles. This provides the ability to de-sensitize the frequency based protection element against oscillations in the power system frequency. The 12-cycle averaging window setting improves measurement accuracy, but slows down the protection start time following fault inception. The maximum fault detection start time following fault inception can be approximated as follows:

Fault Detection Delay Time (cycles) = 2 X M + 1

Where M = No. of frequency averaging cycles "**df/dt.Av. Cycles**"

When enabled, the following signals are set by the df/dt logic according to the status of the monitored function.

df/dt> Inhibit	(DDB 592)	Inhibit all 4 stages when high
df/dt>1 Tmr. Block	(DDB 593)	Block timer on 1st stage when high
df/dt>2 Tmr. Block	(DDB 594)	Block timer on 2nd stage when high
df/dt>3 Tmr. Block	(DDB 595)	Block timer on 3rd stage when high
df/dt>4 Tmr. Block	(DDB 596)	Block timer on 4th stage when high
df/dt>1 Start	(DDB 597)	1st stage started when high
df/dt>2 Start	(DDB 598)	2nd stage started when high
df/dt>3 Start	(DDB 599)	3rd stage started when high
df/dt>4 Start	(DDB 600)	4th stage started when high
df/dt>1 Trip	(DDB 601)	1st stage tripped when high
df/dt>2 Trip	(DDB 602)	2nd stage tripped when high
df/dt>3 Trip	(DDB 603)	3rd stage tripped when high
df/dt>4 Trip	(DDB 604)	4th stage tripped when high

All the above signals are available as DDB signals for mapping in Programmable Scheme Logic (PSL).

1.37 Special Weak Infeed Logic for Stub End Transformer Terminals

The true weak infeed condition is when no current based protection element is sensitive enough to operate. This is the case when zero or minimal generation is connected at that terminal, and the prospective level of fault current flowing through the CT is insufficient for any forward/reverse protection operation. In such cases, the fault will be cleared using either POR or Blocking schemes and enabling WI Echo + Trip.

However, there could be a specific configuration as presented in Figure 78 that may not be detected by relay as a weak infeed condition, even if there is no generation at that end (left side - relay R2).

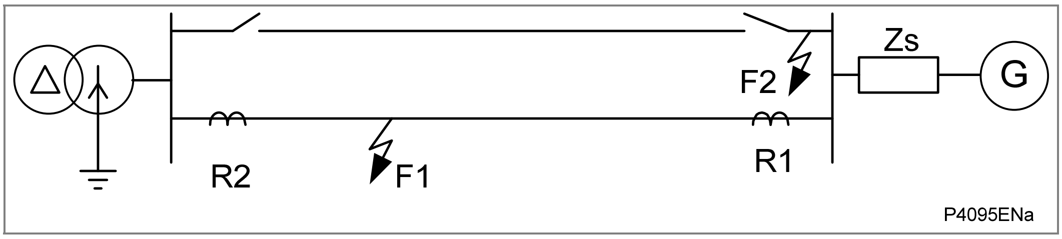


Figure 78 - Weak infeed config on stub-fed radial circuit (parallel line out of service)

The reason is a star earthed transformer which, in case of phase to ground and double phase to ground faults, imposes a very low zero sequence impedance and almost infinite positive and negative sequence impedance, i.e. behaving as a source of zero sequence current only. In such a case, the zero sequence current Io will dominate over I_1 and I_2 at the weak end, where all three phase currents will approximately equal Io (all in phase and equal in magnitude). This is true for F1 earth faults at R2, and for F2 earth faults at R1 and R2. The phase currents will be sufficient to pickup current level detectors in The MiCOM P443/P446, and a true weak infeed condition will not be seen as such by the relay.

In such a stub-end feeding case, relay R2 may experience some overreach in the case of double-phase to ground faults. This is caused by the unusual current distribution making the MiCOM P443/P446 detect a single phase fault condition (and potential single pole tripping only in single pole tripping applications).

For this unusual feeding arrangement, the MiCOM P443/P446 makes available a zero sequence stabilizing feature, that measures the dominance of zero sequence current over negative sequence current ($I_{o/}I_2$). It promotes stability by forcing the relay to recognize the above configuration as a WI condition. It then blocks all distance elements, once the measured $I_{o/}I_2$ ratio exceeds the setting.

2 OPERATION OF NON-PROTECTION FUNCTIONS

The protection functionality of the P443 and the P446 are the same, and a common operational description can be applied. For the non-protection functions, some of the functionality is the same and, similarly, a common operational description can be applied. The principal difference between the P443 and the P446 concerns the number of circuit breakers that can be controlled: The P443 can only control one, whereas the P446 can control two.

For this reason, the circuit breaker monitoring and control software differs between the P443 and P446, and a common operational description cannot be applied. This section describes the operation of the non-protection functions common to both the P443 and P446 that are not associated with circuit breaker monitoring and control. Separate sections are assigned to describe the P443 operational control of a single circuit breaker, and the P446 operational control of dual circuit breakers.

2.1 Voltage Transformer Supervision - Fuse Fail

The voltage transformer supervision (VTS) feature is used to detect failure of the ac voltage inputs to the relay. This may be caused by internal voltage transformer faults, overloading, or faults on the interconnecting wiring to relays. This usually results in one or more VT fuses blowing. Following a failure of the ac voltage input there would be a misrepresentation of the phase voltages on the power system, as measured by the relay, which may result in mal-operation.

The VTS logic in the relay is designed to detect the voltage failure, and automatically adjust the configuration of protection elements whose stability would otherwise be compromised. A time-delayed alarm output is also available.

VTS can be declared by a mini circuit breaker (MCB) status input, by an internal logic using relay measurement or both. A setting “**VTS Mode**” (Measured + MCB /Measured Only/MCB Only) is available to select the method to declare VT failure.

For the measured method, there are three main aspects to consider regarding the failure of the VT supply. These are defined below:

1. Loss of one or two phase voltages
2. Loss of all three phase voltages under load conditions
3. Absence of three phase voltages upon line energization

2.1.1 Loss of One or Two Phase Voltages

The VTS feature within the relay operates on detection of negative phase sequence (nps) voltage without the presence of negative phase sequence current. This gives operation for the loss of one or two phase voltages. Stability of the VTS function is assured during system fault conditions, by the presence of nps current. The use of negative sequence quantities ensures correct operation even where three-limb or ‘**V**’ connected VT’s are used.

Negative Sequence VTS Element:

> The negative sequence thresholds used by the element are V2 = 10V and I2 = 0.05 to 0.5In settable (defaulted to 0.05In).

2.1.2 Loss of all Three Phase Voltages under Load Conditions

Under the loss of all three phase voltages to the relay, there will be no negative phase sequence quantities present to operate the VTS function. However, under such circumstances, a collapse of the three phase voltages will occur. If this is detected without a corresponding change in any of the phase current signals (which would be indicative of a fault), then a VTS condition will be raised. In practice, the relay detects the presence of superimposed current signals, which are changes in the current applied to the relay. These signals are generated by comparison of the present value of the current with that exactly one cycle previously. Under normal load conditions, the value of superimposed current should therefore be zero. Under a fault condition a superimposed current signal will be generated which will prevent operation of the VTS.

The phase voltage level detectors are fixed and will drop off at 10V and pickup at 30V.

The sensitivity of the superimposed current elements is fixed at 0.1In.

2.1.3 Absence of Three Phase Voltages upon Line Energization

If a VT were inadvertently left isolated prior to line energization, incorrect operation of voltage dependent elements could result. The previous VTS element detected three phase VT failure by absence of all 3 phase voltages with no corresponding change in current. On line energization there will, however, be a change in current (as a result of load or line charging current for example). An alternative method of detecting 3 phase VT failure is therefore required on line energization.

The absence of measured voltage on all 3 phases on line energization can be as a result of 2 conditions. The first is a 3 phase VT failure and the second is a close up three phase fault. The first condition would require blocking of the voltage dependent function and the second would require tripping. To differentiate between these 2 conditions an overcurrent level detector (VTS I> Inhibit) is used which will prevent a VTS block from being issued if it operates. This element should be set in excess of any non-fault based currents on line energization (load, line charging current, transformer inrush current if applicable) but below the level of current produced by a close up 3 phase fault. If the line is now closed where a 3 phase VT failure is present the overcurrent detector will not operate and a VTS block will be applied. Closing onto a three phase fault will result in operation of the overcurrent detector and prevent a VTS block being applied.

This logic will only be enabled during a live line condition (as indicated by the relays pole dead logic) to prevent operation under dead system conditions i.e. where no voltage will be present and the VTS I> Inhibit overcurrent element will not be picked up.

Note	*VTS I> Inhibit logic is equally applicable for the situation where loss of all three phase voltages occurs under load conditions. (Refer to section 2.1.2). If the setting of VTS I> Inhibit is less than the load current and if three phase VT fails during normal load, VTS block will not be applied. Hence it is important that the "**VTS I> Inhibit**" is always set above the expected load current.*

2.1.4 VTS Logic

The relay may respond as follows, on operation of any VTS element:

- VTS set to provide alarm indication only;
- Optional blocking of voltage dependent protection elements;
- Optional conversion of directional overcurrent elements to non-directional protection (available when set to Blocking mode only). These settings are found in the Function Links cell of the relevant protection element columns in the menu.

The VTS I> Inhibit or VTS I2> Inhibit elements are used to override a VTS block in event of a fault occurring on the system which could trigger the VTS logic. Once the VTS block has been established, however, then it would be undesirable for subsequent system faults to override the block. The VTS block will therefore be latched after a user settable time delay '**VTS Time Delay**'. Once the signal has latched then two methods of resetting are available. The first is manually via the front panel interface (or remote communications) provided the VTS condition has been removed and secondly, when in ‘**Auto**’ mode, by the restoration of the 3 phase voltages above the phase level detector settings mentioned previously.

A VTS indication will be given after the VTS Time Delay has expired. In the case where the VTS is set to indicate only the relay may potentially mal-operate, depending on which protection elements are enabled. In this case the VTS indication will be given prior to the VTS time delay expiring if a trip signal is given.

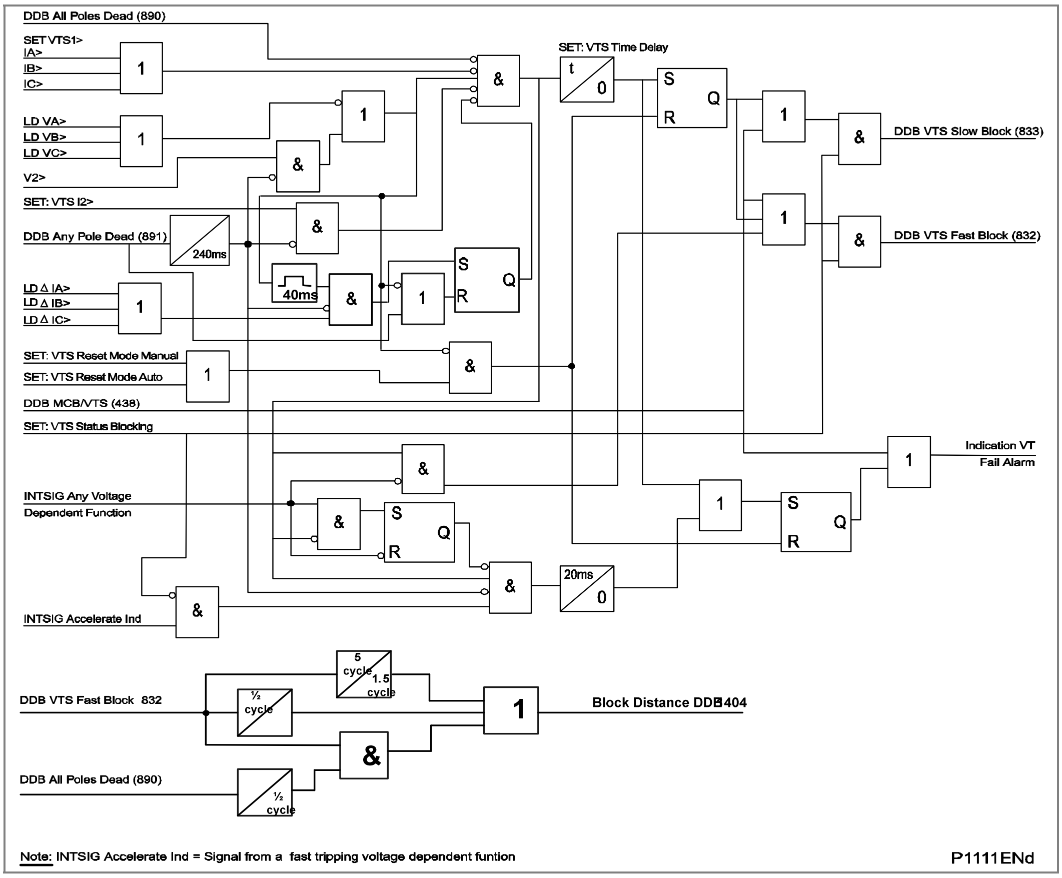

DDB All Poles Dead (890)
SET VTS1>
IA>
IB>
IC>
LD VA>
LD VB>
LD VC>
V2>
SET: VTS I2>
DDB Any Pole Dead (891)
240ms
40ms
LD Δ IA>
LD Δ IB>
LD Δ IC>
SET: VTS Reset Mode Manual
SET: VTS Reset Mode Auto
DDB MCB/VTS (438)
SET: VTS Status Blocking
INTSIG Any Voltage
Dependent Function
INTSIG Accelerate Ind
SET: VTS Time Delay
t
0
S
R
Q
&
1
DDB VTS Slow Block (833)
DDB VTS Fast Block (832)
Indication VT
Fail Alarm
20ms
DDB VTS Fast Block 832
½
cycle
5
cycle
1.5
cycle
Block Distance DDB 404
DDB All Poles Dead (890)
Note: INTSIG Accelerate Ind = Signal from a fast tripping voltage dependent funtion
P1111ENd

Figure 79 - VTS logic

This scheme is also able to correctly operate under very low load or even no load conditions, by the combination of time delayed signals derived from the DDB signals “**VTS Fast block**” and “**all Poles Dead**”, to generate the “**Block Distance**” DDB.

Note	*All non-distance elements are blocked by the “**VTS Fast Block**” DDB.*

Where a Miniature Circuit Breaker (MCB) is used to protect the voltage transformer ac output circuits, it is common to use MCB auxiliary contacts to indicate a three phase output disconnection. As previously described, it is possible for the VTS logic to operate correctly without this input. However, this facility has been provided for compatibility with various utilities current practices. Energizing an opto-isolated input assigned to “**DDB: MCB/VTS**” on the relay will therefore provide the necessary block.

2.2 Current Transformer Supervision

The current transformer supervision feature is used to detect failure of one or more of the ac phase current inputs to the relay. Failure of a phase CT or an open circuit of the interconnecting wiring can result in incorrect operation of any current operated element. Additionally, interruption in the ac current circuits risks dangerous CT secondary voltages being generated.

The CT supervision feature (CTS) operates on detection of derived zero sequence current, in the absence of a corresponding derived zero sequence voltage that would normally accompany it. The voltage transformer connection used must be able to refer zero sequence voltages from the primary to the secondary side. Thus, this element should only be enabled where the VT is of five limb construction, or comprises three single phase units, and has the primary star point earthed.

Operation of the element will produce a time-delayed alarm visible on the LCD, an event record and a DDB 294: CT Fail Alarm, with an instantaneous block (DDB 928: CTS Block) for inhibition of protection elements. Protection elements operating from derived quantities (Broken Conductor, DEF, Earth Fault, Neg Seq O/C) are always blocked on operation of the CT supervision element; other protection can be selectively blocked by customizing the PSL, gating DDB: CTS Block with the protection function logic.

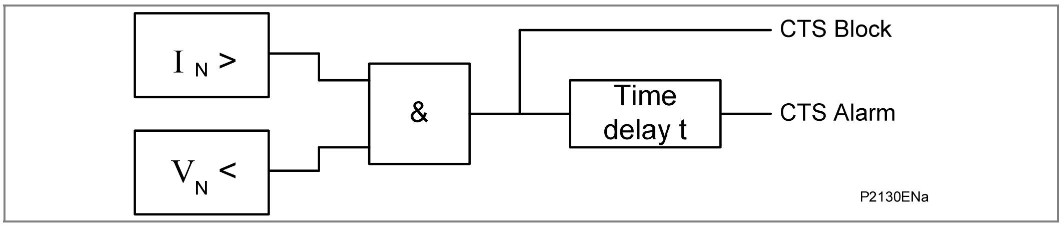


Figure 80 - Voltage dependant CTS

2.3 Transformer Magnetizing Inrush Detector

The MiCOM P443 distance protection has been designed as a fast protection relay. It is therefore not desirable that distance zones should be slowed by forcing them to wait for a detection/no detection of transformer inrush current (in general applications). For this reason, the relay has no second harmonic blocking of the distance elements in the standard protection algorithms.

However should a user wish to employ, for example, a long Zone 1 reach through a transformer, it is possible to implement harmonic blocking for magnetizing inrush current. Provided that the Inrush Detection is “**Enabled**”, the user can then pick up the output of the I(2)/I(1) detectors in the Programmable Scheme Logic. The user can then assign blocking functions in the PSL as necessary, because as stated above this detector does not directly route into the relay’s fixed logic.

2.4 Function Keys

The P443 relay offers users 10 function keys for programming any operator control functionality such as auto-reclose ON/OFF, earth fault1 ON/OFF etc. via PSL. Each function key has an associated programmable tri-color LED that can be programmed to give the desired indication on function key activation.

These function keys can be used to trigger any function that they are connected to as part of the PSL. The function key commands can be found in the '**Function Keys**' menu (see Settings section, P44y/EN ST). In the '**Fn. Key Status**' menu cell there is a 10 bit word which represent the 10 function key commands and their status can be read from this 10 bit word.

In the programmable scheme logic editor 10 function key signals, DDB 1096 - 1105, which can be set to a logic 1 or On state, as described above, are available to perform control functions defined by the user.

The "**Function Keys**" column has '**Fn. Key n Mode**' cell which allows the user to configure the function key as either '**Toggled**' or '**Normal**'. In the '**Toggle**' mode the function key DDB signal output will remain in the set state until a reset command is given, by activating the function key on the next key press. In the '**Normal**' mode, the function key DDB signal will remain energized for as long as the function key is pressed and will then reset automatically. A minimum pulse duration can be programmed for a function key by adding a minimum pulse timer to the function key DDB output signal.

The "**Fn. Key n Status**" cell is used to enable/unlock or disable the function key signals in PSL. The '**Lock**' setting has been specifically provided to allow the locking of a function key thus preventing further activation of the key on consequent key presses. This allows function keys that are set to '**Toggled**' mode and their DDB signal active '**high**', to be locked in their active state thus preventing any further key presses from deactivating the associated function. Locking a function key that is set to the "**Normal**" mode causes the associated DDB signals to be permanently off. This safety feature prevents any inadvertent function key presses from activating or deactivating critical relay functions.

The "**Fn. Key Labels**" cell makes it possible to change the text associated with each individual function key. This text will be displayed when a function key is accessed in the function key menu, or it can be displayed in the PSL.

The status of the function keys is stored in battery backed memory. In the event that the auxiliary supply is interrupted the status of all the function keys will be recorded. Following the restoration of the auxiliary supply the status of the function keys, prior to supply failure, will be reinstated. If the battery is missing or flat the function key DDB signals will set to logic 0 once the auxiliary supply is restored. Please also note the relay will only recognize a single function key press at a time and that a minimum key press duration of approximately 200msec. is required before the key press is recognized in PSL. This deglitching feature avoids accidental double presses.

2.5 Setting Groups Selection

The setting groups can be changed either via opto inputs, via a menu selection, via the hotkey menu or via function keys. In the Configuration column if '**Setting Group - select via optos**' is selected then any opto input or function key can be programmed in PSL to select the setting group as shown in the table below. If '**Setting Group - select via menu**' is selected then in the Configuration column the '**Active Settings - Group1/2/3/4**' can be used to select the setting group.

The setting group can be changed via the hotkey menu providing '**Setting Group select via menu**' is chosen.

Two DDB signals are available in PSL for selecting a setting group via an opto input or function key selection. The following table illustrates the setting group that is active on activation of the relevant DDB signals.

DDB 542 SG Select x1	DDB 543 SG Select 1x	Selected Setting Group
0	0	1
1	0	2
0	1	3
1	1	4

Note	*Each setting group has its own PSL. Once a PSL has been designed it can be sent to any one of 4 setting groups within the relay. When downloading a PSL to the relay the user will be prompted to enter the desired setting group to which it will be sent. This is also the case when extracting a PSL from the relay.*

Table 16 - DDB signals and active setting groups

2.6 Control Inputs

The control inputs function as software switches that can be set or reset either locally or remotely. These inputs can be used to trigger any function that they are connected to as part of the PSL. There are three setting columns associated with the control inputs that are: "**CONTROL INPUTS**", "**CTRL. I/P CONFIG.**" and "**CTRL. I/P LABELS**". The function of these columns is described in the following table:

Menu Text	Default Setting	Setting Range	Step Size
CONTROL INPUTS			
Ctrl I/P Status	00000000000000000000000000000000		
Control Input 1	No Operation	No Operation, Set, Reset	
Control Input 2 to 32	No Operation	No Operation, Set, Reset	

Table 17 - Control inputs

The Control Input commands can be found in the '**Control Input**' menu. In the '**Ctrl. I/P status**' menu cell there is a 32 bit word which represent the 32 control input commands. The status of the 32 control inputs can be read from this 32-bit word. The 32 control inputs can also be set and reset from this cell by setting a 1 to set or 0 to reset a particular control input. Alternatively, each of the 32 Control Inputs can be set and reset using the individual menu setting cells '**Control Input 1, 2, 3**' etc. The Control Inputs are available through the relay menu as described above and also via the rear communications.

In the programmable scheme logic editor 32 Control Input signals, DDB 191 - 223, which can be set to a logic 1 or On state, as described above, are available to perform control functions defined by the user.

Menu Text	Default Setting	Setting Range	Step Size
CTRL. I/P CONFIG.			
Hotkey Enabled	11111111111111111111111111111111		
Control Input 1	Latched	Latched, Pulsed	
Ctrl Command 1	Set/Reset	Set/Reset, In/Out, Enabled/Disabled, On/Off	
Control Input 2 to 32	Latched	Latched, Pulsed	
Ctrl Command 2 to 32	Set/Reset	Set/Reset, In/Out, Enabled/Disabled, On/Off	

Table 18 - Ctrl. I/P config

Menu Text	Default Setting	Setting Range	Step Size
CTRL. I/P LABELS			
Control Input 1	Control Input 1	16 character text	
Control Input 2 to 32	Control Input 2 to 32	16 character text	

Table 19 - Ctrl. I/P labels

The "**CTRL. I/P CONFIG.**" column has several functions one of which allows the user to configure the control inputs as either '**latched**' or '**pulsed**'. A latched control input will remain in the set state until a reset command is given, either by the menu or the serial communications. A pulsed control input, however, will remain energized for 10ms after the set command is given and will then reset automatically (i.e. no reset command required).

In addition to the latched/pulsed option this column also allows the control inputs to be individually assigned to the "**Hotkey**" menu by setting '**1**' in the appropriate bit in the "**Hotkey Enabled**" cell. The hotkey menu allows the control inputs to be set, reset or pulsed without the need to enter the "**CONTROL INPUTS**" column. The "**Ctrl. Command**" cell also allows the SET/RESET text, displayed in the hotkey menu, to be changed to something more suitable for the application of an individual control input, such as "**ON/OFF**", "**IN/OUT**" etc.

The "**CTRL. I/P LABELS**" column makes it possible to change the text associated with each individual control input. This text will be displayed when a control input is accessed by the hotkey menu, or it can be displayed in the PSL.

Note *With the exception of pulsed operation, the status of the control inputs is stored in non volatile memory. In the event that the auxiliary supply is interrupted the status of all the inputs will be recorded. Following the restoration of the auxiliary supply the status of the control inputs, prior to supply failure, will be reinstated. If the battery is missing or flat the control inputs will set to logic 0 once the auxiliary supply is restored.*

2.7 Real Time Clock Synchronization via Opto-Inputs

In modern protective schemes it is often desirable to synchronize the relays real time clock so that events from different relays can be placed in chronological order. This can be done using the IRIG-B input, if fitted, or via the communication interface connected to the substation control system. In addition to these methods The MiCOM P443/P446 range offers the facility to synchronize via an opto-input by routing it in PSL to DDB 400 (Time Sync.). Pulsing this input will result in the real time clock snapping to the nearest minute. The recommended pulse duration is 20ms to be repeated no more than once per minute. An example of the time sync. function is shown.

Time of "Sync. Pulse"	Corrected Time
19:47:00 to 19:47:29	19:47:00
19:47:30 to 19:47:59	19:48:00
Note The above assumes a time format of hh:mm:ss.	

Table 20 - Time of "sync. pulse" and corrected time

To avoid the event buffer from being filled with unnecessary time sync. events, it is possible to ignore any event that is generated by the time sync. opto input. This can be done by applying the following settings:

Menu Text	Value
RECORD CONTROL	
Opto Input Event	Enabled
Protection Event	Enabled
DDB 63 - 32 (Opto Inputs)	Set "Time Sync." associated opto to 0

Table 21 - Record control

To improve the recognition time of the time sync. opto input by approximately 10ms, the opto input filtering could be disabled. This is achieved by setting the appropriate bit to 0 in the "**Opto Filter Cntl.**" cell (OPTO CONFIG. column). Disabling the filtering may make the opto input more susceptible to induced noise. Fortunately the effects of induced noise can be minimized by using the methods described in the Firmware Design section (P44y/EN FD).

2.8 Read Only Mode

With IEC 61850 and Ethernet/Internet communication capabilities, security has become a pressing issue. The Px40 relay provides a facility to allow the user to enable or disable the change in configuration remotely. This feature is available only in relays with Courier, Courier with IEC 60870-5-103 and Courier with IEC 61850 protocol options. It has to be noted that in IEC 60870-5-103 protocol, Read Only Mode function is different from the existing Command block feature.

2.8.1 Protocol/Port Implementation:

2.8.1.1 IEC 60870-5-103 protocol on rear port 1:

The protocol does not support settings but the indications, measurands and disturbance records commands are available at the interface.

Allowed:

Poll Class 1 (read spontaneous events)
Poll Class 2 (read measurands)
GI sequence (ASDU7 '**Start GI**', Poll Class 1)
Transmission of Disturbance Records sequence (ASDU24, ASDU25, Poll Class 1)
Time Synchronization (ASDU6)
General Commands (ASDU20), namely:
INF23 activate characteristic 1
INF24 activate characteristic 2
INF25 activate characteristic 3
INF26 activate characteristic 4

Blocked:

Write parameter (=change setting) (private ASDUs)
General Commands (ASDU20), namely:
INF16 auto-recloser on/off
INF19 LED reset
Private INFs (e.g. CB open/close, control inputs)

2.8.1.2 Courier Protocol on Rear Port 1/2 and Ethernet

Allowed:

Read settings, statuses, measurands
Read records (event, fault, disturbance)
Time Synchronization
Change active setting group

Blocked:

Write settings
All controls, including:
Reset Indication (Trip LED)
Operate control inputs
CB operations
Auto-reclose operations
Reset demands
Clear event/fault/maintenance/disturbance records
Test LEDs & contacts

2.8.1.3 IEC 61850

Allowed:

Read statuses, measurands
Generate reports
Extract disturbance records
Time synchronization
Change active setting group

Blocked:

All controls, including:
Enable/disable protection
Operate control inputs
CB operations (Close/Trip, Lock)
Reset LEDs

2.8.2 Courier Database Support

Three new settings, one for each remote communications port at the back of the relay are created to support the enabling and disabling of the Read Only mode at each port.

The **NIC Read Only** setting will apply to all the communications protocols (including the Tunnelled Courier) that are transmitted via the Ethernet Port. Their default values are **Disabled**.

The DNP3 communication interface that do not support the feature will ignore these settings.

2.8.3 New DDB Signals

The remote Read Only mode is also available in the PSL via three dedicated DDB signals:

- RP1 Read Only
- RP2 Read Only
- NIC Read Only

Through careful scheme logic design, the activations of these Read Only signals can be facilitated via Opto Inputs, Control Inputs and Function Keys.

These DDBs are available in every build, however they are effective only in Courier, IEC 60870-5-103 build and in latest IEC 61850 (firmware version 57 onwards). The setting cells are not available in DNP3.0.

2.9 Fault Locator

The relay has an integral fault locator that uses information from the current and voltage inputs to provide a distance to fault location. The sampled data from the analog input circuits is written to a cyclic buffer until a fault condition is detected. The data in the input buffer is then held to allow the fault calculation to be made. When the fault calculation is complete the fault location information is available in the relay fault record.

When applied to parallel circuits mutual flux coupling can alter the impedance seen by the fault locator. The coupling will contain positive, negative and zero sequence components. In practice the positive and negative sequence coupling is insignificant. The effect on the fault locator of the zero sequence mutual coupling can be eliminated by using the mutual compensation feature provided.

2.9.1 Basic Theory for Ground Faults

Figure 81 shows a two-machine equivalent circuit of a faulted power system.

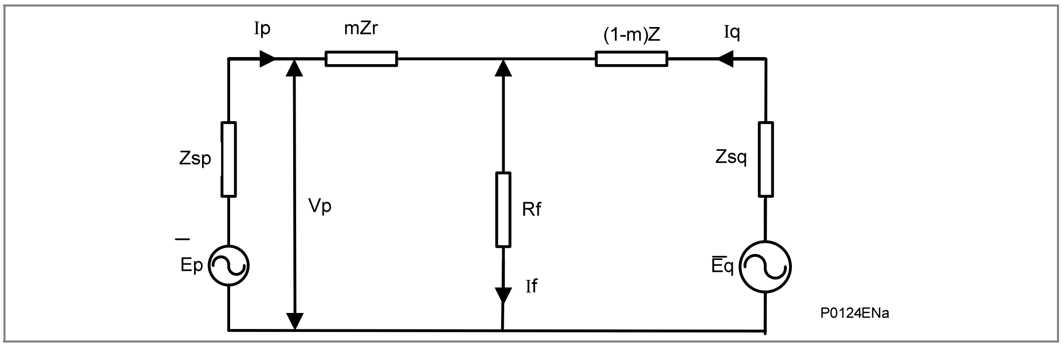


Figure 81 - Two-machine equivalent circuit

From this diagram:

Vp = mIpZr + IfRf …(equation 1)

The fault location, m, can be found if □f can be estimated by solving equation 1.

2.9.2 Data Acquisition and Buffer Processing

The fault locator stores the sampled data within a 12 cycle cyclic buffer at a resolution of 48 samples per cycle. When the fault recorder is triggered the data in the buffer is frozen such that the buffer contains 6 cycles of pre-trigger data and 6 cycles of post-trigger data. Fault calculation commences shortly after this trigger point.
The trigger for the fault recorder is user selectable via the programmable scheme logic.
The fault locator can store data for up to four faults. This ensures that fault location can be calculated for all shots on a typical multiple reclose sequence.

2.9.3 Faulted Phase Selection

Phase selection is derived from the superimposed current phase selector.
Phase selection and fault location calculations can only be made if the current change exceeds 5% In.

2.9.4 The Fault Location Calculation

The fault location calculation works by:

1. First obtaining the vectors
2. Selecting the faulted phase(s)

3. Estimating the phase of the fault current If for the faulted phase(s)
4. Solving equation 1 for the fault location m at the instant of time where f = 0

2.9.5 Obtaining the Vectors

Different sets of vectors are chosen depending on the type of fault identified by the phase selection algorithm. The calculation using equation 1 is applied for either a phase to ground fault or a phase to phase fault.

Thus for an A phase to ground fault:

IpZr=Ia(Zline/THETA line) + In (Zresidual/THETA residual) ...(equation 2)

and Vp=VA

and for an A phase to B phase fault:

IpZr=Ia(Zline/THETA line) - Ib (Zresidual / THETA residual) ...(equation 3)

and Vp = VA - VB

The calculation for a ground fault (equation 4) is modified when mutual compensation is used:

IpZr=Ia(Zline/THETA line) +In (residual/THETA residual)+

Im(mutual/THETA mutual) ...(equation 4)

2.9.6 Solving the Equation for the Fault Location

As the sine wave of If passes through zero, the instantaneous values of the sine waves Vp and Ip can be used to solve equation (1) for the fault location m. (The term IfRf being zero).

This is determined by shifting the calculated vectors of Vp and IpZr by the angle (90° - angle of fault current) and then dividing the real component of Vp by the real component of IpZr. (See Figure 82).

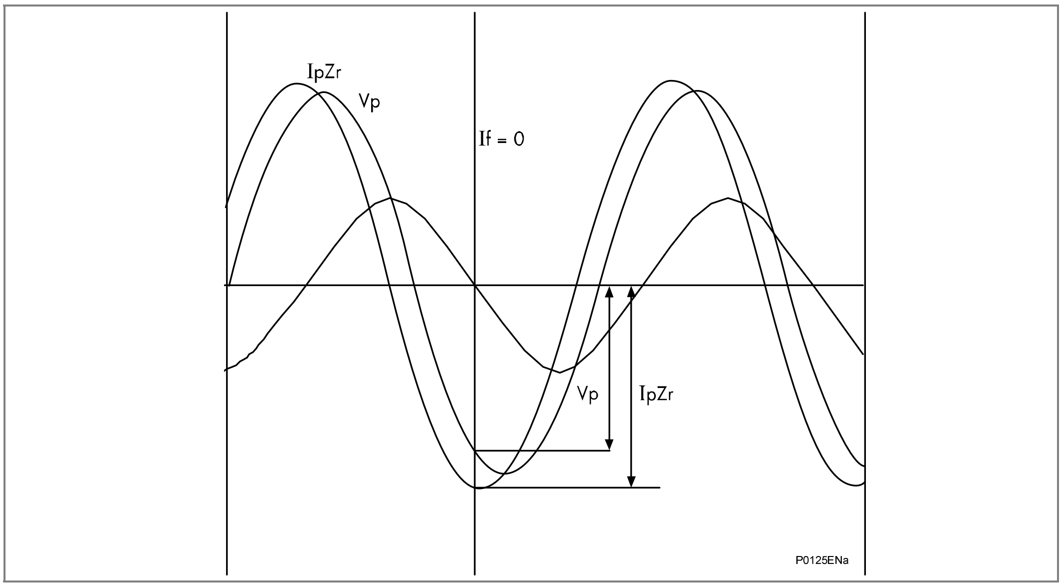


Figure 82 - Fault locator selection of fault current zero

i.e.:

Phase advanced vector Vp

= │ Vp │ [cos(s) + jsin(s)] * [sin(d) + jcos(d)]

$= |Vp|$ [-sin(s-d) + jcos(s-d)]

Phase advanced vector IpZr

$= |IpZr|$ [cos (e) + jsin (e)] * [sin (d) + jcos (d)]

$= |IpZr|$ [-sin(e-d) + jcos(e-d)]

Therefore, from equation 1:

m = Vp ÷ (Ip * Zr) at If = 0

= Vp sin(s-d)/(IpZr * sin(e-d))

Where:

d = Angle of fault current If

s = Angle of Vp

e = Angle of IpZr

Thus the relay evaluates m which is the fault location as a percentage of the fault locator line impedance setting and then calculates the output fault location by multiplying this by the line length setting. When calculated the fault location can be found in the fault record under the VIEW RECORDS column in the Fault Location cells. Distance to fault is available in kilometers, miles, impedance or percentage of line length.

2.9.7 Mutual Compensation

Analysis of a ground fault on one circuit of a parallel over-head line shows that a fault locator positioned at one end of the faulty line will tend to over-reach while that at the other end will tend to under-reach. In cases of long lines with high mutual inductance, mutual zero sequence compensation can be used to improve the fault locator accuracy. The compensation is achieved by taking an input to the relay from the residual circuit of the current transformers in the parallel line.

The MiCOM P443 provides mutual compensation for both the fault locator function, AND the distance protection zones.

3 SINGLE CB CONTROL: P443 OPERATIONAL DESCRIPTION

This section describes the P443 operational control of a single Circuit Breaker (CB).

The CB control and monitoring in the P443 provides single phase or three phase switching of a feeder controlled by a single CB.

3.1 P443 Single and Three Phase Auto-Reclosing

3.1.1 P443 Time Delayed and High Speed Auto-Reclosing

The MiCOM P443 will initiate auto-reclosure following any Zone 1, or distance-aided scheme trips which occur. In addition, the user can selectively decide to auto-reclose for trips from time-delayed distance zones, overcurrent and earth (ground) elements, and DEF aided schemes.

The auto-reclose function offers multi-shot auto-reclose control, selectable to perform up to a four shot cycle. Dead times (Note 1) for all shots (Note 2) are independently adjustable. Should the CB close successfully at the end of the dead time, a “**Reclaim Time**” starts. If the circuit breaker does not trip again, the auto-reclose function resets at the end of the reclaim time. If the protection trips again during the reclaim time the relay advances to the next shot in the programmed cycle, or, if all programmed reclose attempts have been made, goes to lockout.

Note 1	*“**Dead Time**” denotes the open (dead) interval delay of the CB*
Note 2	*A “**Shot**” is a reclosure attempt*

Logic diagrams to explain the operation of the auto-reclose feature are grouped together at the end of this section.

3.1.2 P443 Auto-Reclose Logic Inputs

The auto-reclose function uses inputs in the logic, which can be assigned and activated from any of the opto-isolated inputs on the relay via the Programmable Scheme Logic (PSL). Contacts from external equipment may be used to influence the auto-recloser via the optos, noting that the CB Status (open/closed) must also be available via auxiliary contact inputs to the relay.

These logic inputs can also be assigned and activated from other sources. The function of these inputs is described below, identified by their DDB signal text. The inputs can be selected to accept either a normally open or a normally closed contact, programmable via the PSL editor.

3.1.2.1 P443 CB Healthy

The majority of circuit breakers are only capable of providing one trip-close-trip cycle. Following this, it is necessary to re-establish sufficient energy in the circuit breaker before the CB can be re-closed. The CB Healthy input is used to ensure that there is sufficient energy available to close and trip the CB before initiating a CB close command. If on completion of the dead time, sufficient energy is not detected by the relay from the CB Healthy input for a period given by the CB Healthy time timer, lockout will result and the CB will remain open.

3.1.2.2 P443 BAR

The “**BAR**” input will block auto-reclose and cause a lockout if auto-reclose is in progress. It can be used when protection operation without auto-reclose is required.

3.1.2.3 P443 Reset Lockout

The “**Reset Lockout**” input can be used to reset the auto-reclose function following lockout and reset any auto-reclose alarms, provided that the signals which initiated the lockout have been removed.

3.1.2.4 P443 Pole Discrepancy

Circuit breakers with independent mechanisms for each pole normally incorporate a ‘**phases not together**’ or ‘**pole discrepancy**’ protection device which automatically trips all three phases if they are not all in the same position i.e. all open or all closed.

During single pole auto-reclosing a pole discrepancy condition is deliberately introduced and the pole discrepancy device must not operate for this condition. This may be achieved by using a delayed action pole discrepancy device with a delay longer than the single pole auto-reclose dead time, ‘**1 Pole Dead Time**’. Alternatively, a signal can be given from the relay during the single pole auto-reclose dead time, “**AR 1 Pole In Progress**”, to inhibit the pole discrepancy device.

The “**Pole Discrepancy**” input is activated by a signal from an external device indicating that all three poles of the CB are not in the same position. The “**Pole Discrepancy**” input forces a 3 pole trip which will cancel any single pole auto-reclose in progress and start three pole auto-reclose in progress.

3.1.2.5 P443 Enable 1 Pole AR

The “**En 1 Pole Re-close**” input is used to select the single phase auto-reclose operating mode.

3.1.2.6 P443 Enable 3 Pole AR

The “**En 3 Pole Re-close**” input is used to select the three phase auto-reclose operating mode.

3.1.2.7 P443 External Trip

The “**External Trip 3Ph**” input and the “**External Trip A**”, “**External Trip B**” and “**External Trip C**” inputs can be used to initiate three or single phase auto-reclose.

Note	*These signals are not used to trip the CB but do initiate auto-reclose. To trip the CB directly they could be assigned to the trip contacts of the relay in the PSL.*

3.1.3 P443 Internal Signals

3.1.3.1 P443 Trip Initiate Signals

The “**Trip Inputs A**”, “**Trip Inputs B**” and “**Trip Inputs C**” signals are used to initiate signals or three phase auto-reclose.

Note	*For single phase auto-reclose these signals must be mapped in the PSL as shown in the default.*

3.1.3.2 P443 Circuit Breaker Status

The “**CB Open 3 ph**”, “**CB Open A ph**”, “**CB Open B p**h” and “**CB Open C ph**”, signals are used to indicate if a CB is open three or single phase. These are driven from the internal pole dead logic and the CB auxiliary inputs.

The “**CB Closed 3 ph**”, “**CB Closed A ph**”, “**CB Closed B ph**” and “**CB Closed C ph**”, signals are used to indicate if a CB is closed three or single phase. These are driven from the internal pole dead logic and the CB auxiliary inputs.

3.1.3.3 P443 Check Synch Ok and System Check OK

Internal signals generated from the internal system check function and external system check equipment are used by the internal auto-reclose logic to permit auto-reclosure.

3.1.4 P443 Auto-Reclose Logic Outputs

The following DDB signals can be masked to a relay contact in the PSL or assigned to a Monitor Bit in “**Commissioning Tests**”, to provide information about the status of the auto-reclose cycle. These are described below, identified by their DDB signal text.

3.1.4.1 P443 AR 1 pole in progress

The “**AR 1 Pole in Progress**” output indicates that single pole auto-reclose is in progress. The output is on from protection initiation to the end of the single pole dead time, “**1 Pole Dead Time**”.

3.1.4.2 P443 AR 3 Pole in Progress

The “**AR 3 Pole in Progress**” output indicates that three pole auto-reclose is in progress. The output is on from protection initiation to the end of the three pole dead time, ‘**Dead Time 1, 2, 3, 4**’.

3.1.4.3 P443 Successful Close

The “**AR Successful Reclose**” output indicates that an auto-reclose cycle has been successfully completed. A successful auto-reclose signal is given after the CB has tripped from the protection and re-closed whereupon the fault has been cleared and the reclaim time has expired resetting the auto-reclose cycle. The successful auto-reclose output is reset at the next CB trip or from one of the reset lockout methods; see section 3.1.2.3 ‘**Reset from lockout**’.

3.1.4.4 P443 AR Status

The “**A/R In Status 1P**” output indicates that the relay is in the single phase auto-reclose mode. The “**A/R In Status 3P**” output indicates that the relay is in the three phase auto-reclose mode.

3.1.4.5 P443 Auto Close

The “**Auto Close**” output indicates that the auto-reclose logic has issued a close signal to the CB. This output feeds a signal to the control close pulse timer and remains on until the CB has closed. This signal may be useful during relay commissioning to check the operation of the auto-reclose cycle. This signal is combined with the manual close signal to produce the signal “**Control Close**” which should be mapped to an output contact.

3.1.5 P443 Auto-Reclose Alarms

The following DDB signals will produce a relay alarm. These are described below, identified by their DDB signal text.

3.1.5.1 P443 AR No Checksync (Latched)

The “**AR No Checksync**” alarm indicates that the system voltages were not in synchronism at the end of the “**Check Sync Time**”, leading to a lockout condition. This alarm can be reset using one of the reset lockout methods; see section 3.1.2.3 ‘**Reset from lockout**’.

3.1.5.2 P443 AR CB Unhealthy (Latched)

The “**AR CB Unhealthy**” alarm indicates that the “**CB Healthy**” input was not energized at the end of the “**CB Healthy Time**”, leading to a lockout condition. The “**CB Healthy**” input is used to indicate that there is sufficient energy in the CB operating mechanism to close and trip the CB at the end of the dead time. This alarm can be reset using one of the reset lockout methods; see section 3.1.2.3 ‘**Reset from lockout**’.

3.1.5.3 P443 AR Lockout (Self Reset)

The “**AR Lockout**” alarm indicates that the relay is in a lockout state and that further reclose attempts will not be made; see section 3.1.5.3 ‘**AR Lockout**’ for more details. This alarm can be reset using one of the reset lockout methods; see section 3.1.2.3 ‘**Reset from lockout**’.

3.1.6 P443 Auto-Reclose Logic Operating Sequence

An auto-reclose cycle can be internally initiated by operation of a protection element, provided the circuit breaker is closed until the instant of protection operation. The user can, via a setting, determine if the auto-reclose shall be initiated on the rising edge of the protection trip (Protection Op) or on the falling edge (Protection Reset).

If single pole auto-reclose [A/R Status 1P] only is enabled then if the first fault is a single phase fault the single pole dead time ("**1 Pole Dead Time**") and single pole auto-reclose in progress [AR 1pole in prog] starts on the rising or falling edge (according to the setting) of the single phase trip. If the relay has been set to allow more than one single pole reclose [Single Pole Shot >1] then any subsequent single phase faults will be converted to 3 pole trips. The three pole dead times ("**Dead Time 2, Dead Time 3, Dead Time 4**") [Dead Time 2, 3, 4] and three pole auto-reclose in progress [AR 3pole in prog] will start on the rising or falling edge (according to the setting) of the three pole trip for the 2nd, 3rd and 4th trips [shots]. For a multi-phase fault the relay will lockout on the rising or falling edge (according to the setting) of the three phase trip.

If three pole auto-reclose [A/R Status 3P] only is enabled then for any fault the three pole dead time ("**Dead Time 1, Dead Time 2, Dead Time 3, Dead Time 4**") [Dead Time 1, 2, 3, 4] and three pole auto-reclose in progress [AR 3pole in prog] starts on the rising or falling edge (according to the setting) of the three phase trip. The logic forces a 3 pole trip [Force 3 pole AR] for any single phase fault if three pole auto-reclose [A/R Status 3P] only is enabled.

If single [A/R Status 1P] and three phase auto-reclose [A/R Status 3P] are enabled then if the first fault is a single phase fault the single pole dead time ("**1 Pole Dead Time**") [1 Pole Dead Time] and single pole auto-reclose in progress [AR 1pole in prog] starts on the rising or falling edge (according to the setting) of the single phase trip. If the first fault is a multi-phase fault the three pole dead time ("**Dead Time 1**") and three pole auto-reclose in progress [AR 3pole in prog] starts on the rising or falling edge (according to the setting) of the three phase trip. If the relay has been set to allow more than one reclose [Three Pole Shot >1] then any subsequent faults will be converted to 3 pole trips [Force 3 pole AR]. The three pole dead times ("**Dead Time 2, Dead Time 3, Dead Time 4**") [Dead Time 2, 3, 4] and three pole

auto-reclose in progress [AR 3pole in prog] will start on the rising or falling edge (according to the setting) of the three pole trip for the 2nd, 3rd and 4th trips [shots]. If a single phase fault evolves to a multi-phase fault during the single pole dead time [1 Pole

Dead Time] then single pole auto-reclose in progress [AR 1pole in prog] is stopped and the three pole dead time [Dead Time 1] and three pole auto-reclose in progress [AR 3pole in prog] is started.

At the end of the relevant dead time, the auto-reclose single phase or three phase in progress signal is reset and a CB close signal is given, provided system conditions are suitable. The system conditions to be met for closing are that the system voltages are in synchronism or dead line/live bus or live line/dead bus conditions exist, indicated by the internal check synchronizing element and that the circuit breaker closing spring, or other energy source, is fully charged indicated from the “**CB Healthy**” input. The CB close signal is cut-off when the circuit breaker closes. For single pole auto-reclose no voltage or synchronism check is required as synchronizing power is flowing in the two healthy phases. Check synchronizing for the first three phase cycle is controlled by a setting.

When the CB has closed the reclaim time (“**Reclaim Time**”) starts. If the circuit breaker does not trip again, the auto-reclose function resets at the end of the reclaim time. If the protection operates during the reclaim time the relay either advances to the next shot in the programmed auto-reclose cycle, or, if all programmed reclose attempts have been made, goes to lockout.

Every time the relay trips the sequence counter is incremented by 1. The relay compares the “**Single Pole Shots**” and “**Three Pole Shots**” counter values to the sequence count. If the fault is single phase and the sequence count is greater than the “**Single Pole Shots**” setting then the relay will lockout. If the fault is multi-phase phase and the sequence count is greater than the “**Three Pole Shots**” setting then the relay will also lockout.

For example, if “**Single Pole Shots**” = 2 and “**Three Pole Shots**” = 1, after two phase-phase faults the relay will lockout because the sequence count = 2 which is greater than the “**Three Pole Shots**” target of 1 and the second fault was a multi-phase fault. If there was a permanent earth fault the relay would trip and reclose twice and on the third application of earth fault current it would lockout. This is because on the third application of fault current the sequence count would be greater than the “**Single Pole Shots**” target of 2 and the third fault was an earth fault. There is no lockout at the second trip because the second trip was single phase and the sequence count is not greater than the “**Single Pole Shots**” target of 2. If there was a single phase fault which evolved to a phase-phase-ground fault then the relay would trip and reclose and on the second multi-phase fault would lockout. This is because on the second application of fault current the sequence count is greater than the “**Three Pole Shots**” target of 1 and the second fault was a multi-phase fault.

The total number of auto-reclosures is shown in the CB Control menu under “**Total Reclosures**”. This value can be reset to zero with the “**Reset Total A/R**” command.

The selection of which protection is used to initiate auto-reclose can be made using the settings “**Initiate AR, No Action or Block AR**” for the protection functions listed in the auto-reclose menu. See section 3.1.7.2 ‘**Auto-reclose Initiation**’ for more details.

For multi-phase faults the auto-reclose logic can be set to allow auto-reclose block for 2 and 3 phase faults or to block auto-reclose for 3 phase faults only using the setting “**Multi Phase AR - Allow AR/BAR 2 & 3 Phase/BAR 3 Phase**” in the Auto-reclose settings.

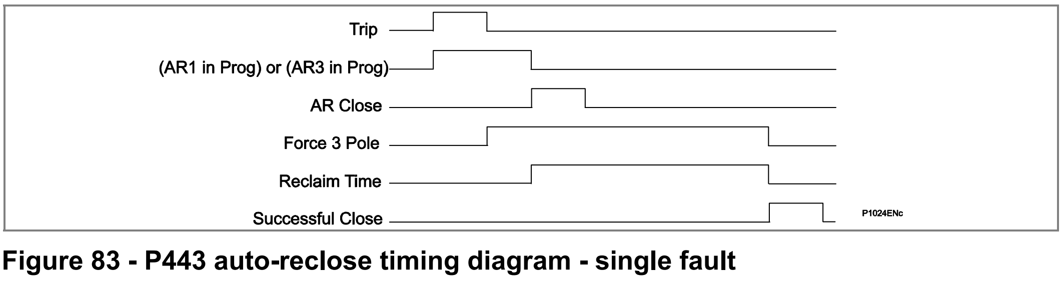


Figure 83 - P443 auto-reclose timing diagram - single fault

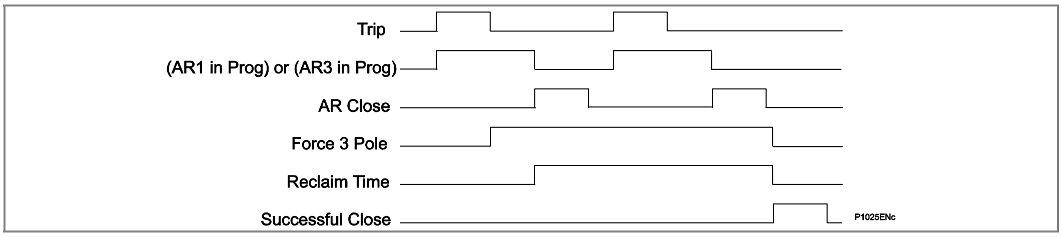

Trip
(AR1 in Prog) or (AR3 in Prog)
AR Close
Force 3 Pole
Reclaim Time
Successful Close
P1025ENc

Figure 84 - P443 auto-reclose timing diagram - repeated fault inception

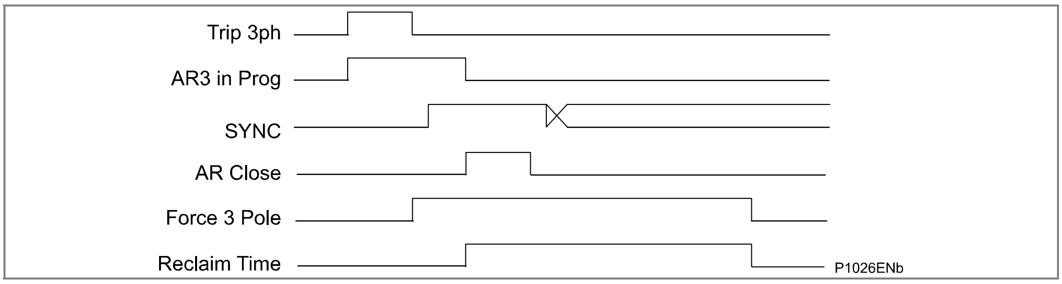

Trip 3ph
AR3 in Prog
SYNC
AR Close
Force 3 Pole
Reclaim Time
P1026ENb

Figure 85 - P443 auto-reclose timing diagram - fault with system synchronism

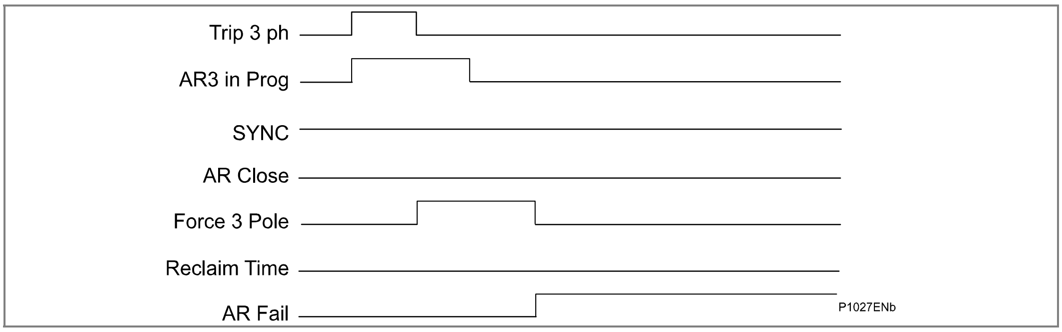

Trip 3 ph
AR3 in Prog
SYNC
AR Close
Force 3 Pole
Reclaim Time
AR Fail
P1027ENb

Figure 86 - P443 auto-reclose timing diagram - lockout for no checksynch

3.1.7 P443 Auto-Reclose Main Operating features

3.1.7.1 P443 Auto-Reclose Modes

The auto-reclose function has three operating modes:

- Single Pole Auto-reclose
- Three Pole Auto-reclose
- Single/Three Pole Auto-reclose

Single pole and three pole auto-reclose modes can be selected from opto inputs assigned for “**En 1 Pole Reclose**” and “**En 3 Pole Reclose**” respectively. Energizing both opto inputs would select the single/three pole operating mode. Alternatively, the settings “**Single Pole A/R - Enabled/Disabled**” and “**Three Pole A/R - Enabled/Disabled**” in the CB Control menu can also be used to select the operating modes. How these operating modes affect the operating sequence is described above.

3.1.7.2 P443 Auto-Reclose Initiation

Auto-reclose is initiated from the internal protection of the relay. The distance zones, DEF aided, overcurrent and earth fault protection can be selected to “**Initiate AR, No Action or Block AR**” in the Auto-reclose settings.

- By default, all “**instantaneous**” schemes will initiate auto-reclose, Zone 1 distance, Aided Scheme 1, and Aided Scheme 2 will all initiate AR.

- For these instantaneous tripping elements, it is possible to override initiation for user set combinations of multi-phase faults if required, by use of the '***Multi Phase AR'*** Block setting. This will prevent auto-reclose initiation, and drive the sequence to lockout.

3.1.7.3 P443 Auto-Reclose Inhibit following Manual Close

The AR Inhibit Time setting can be used to prevent auto-reclose being initiated when the CB is manually closed onto a fault. Auto-reclose is disabled for the AR Inhibit Time following manual CB closure.

3.1.7.4 P443 AR Lockout

If protection operates during the reclaim time, following the final reclose attempt, the relay will be driven to lockout and the auto-reclose function will be disabled until the lockout condition is reset. This will produce an alarm, "**AR Lockout**".

The block auto-reclose logic in the relay will also cause an auto-reclose lockout if auto-reclose is in progress. The "**BAR**" input assigned to an opto input will block

auto-reclose and cause a lockout if auto-reclose is in progress. The auto-reclose logic can also be set to block auto-reclose for 2 and 3 phase faults or to block auto-reclose for 3 phase faults only using the setting "**Multi Phase AR - Allow AR/BAR 2&3 Phase/BAR 3 Phase**" in the Auto-reclose menu. Also, the protection functions can be individually selected to block auto-reclose using the settings, "**Initiate AR, No Action or Block AR**" in the auto-reclose menu.

Auto-reclose lockout can also be caused by the CB failing to close because the CB springs are not charged/low gas pressure or there is no synchronism between the system voltages indicated by the "**AR CB Unhealthy**" and "**AR No Checksync**" alarms.

An auto-reclose lockout is also given if the CB is open at the end of the reclaim time.

Note *Lockout, can also be caused by the CB condition monitoring functions maintenance lockout, excessive fault frequency lockout, broken current lockout, CB failed to trip and CB failed to close and manual close - no check synchronism and CB unhealthy. These lockout alarms are mapped to a composite signal "**CB Lockout Alarm**".*

3.1.7.5 P443 Reset from Lockout

The "**Reset Lockout**" input assigned to an opto input can be used to reset the auto-reclose function following lockout and reset any auto-reclose alarms, provided that the signals which initiated the lockout have been removed. Lockout can also be reset from the clear key or the CB CONTROL command "**Lockout Reset**".

The "**Reset Lockout**" by setting, "**CB Close/User interface**" in CB CONTROL is used to enable/ disable reset of lockout automatically from a manual close after the manual close time "**AR Inhibit Time**".

3.1.7.6 P443 System Check on Shot 1

The "**SysChk on Shot 1**" setting is used to "**Enable/Disable**" system checks for the first reclose after a 3 pole trip in an auto-reclose cycle. When the "**SysChk on Shot 1**" is set to "**Disabled**" no system checks are required for the first reclose which may be preferred when high speed auto-reclose is applied to avoid the extra time for a system check. Subsequent reclose attempts in a multi-shot cycle will still require a system check.

3.1.7.7 P443 Immediate Auto-Reclose with Check Synchronism

The CS AR Immediate setting allows immediate auto-reclosure without waiting for the expiry of the settable dead time, provided the check synchronism conditions are met and a fault is not detected. The intention is to allow the local end to reclose immediately if the remote end has already re-closed successfully and the synchronizing conditions are met.

This feature applies when the setting is enabled. It applies to all dead times, just for three pole auto-reclose and just for Live Line-Live Bus condition (plus other check synchronizing conditions of phase angle, frequency etc).

When set to disabled the relay will wait for the relevant dead time.

3.1.7.8 P443 Discrimination Timer Setting

A single-phase fault can result in a single-phase trip and a single-pole auto-reclose cycle will be started, however the fault may evolve during the dead time to affect another phase. For an evolving fault, the protection issues a three-phase trip.

The discrimination timer starts simultaneously with the dead time timer, and is used to discriminate from which point in time an evolving fault is identified as no longer one continued evolution of the first fault, but is now a discrete second fault condition. If the evolving fault occurs before the expiry of the discrimination time, the protection will start a three-pole auto-reclose cycle if permitted. If however, the second phase fault occurs after the discrimination time, the automatic reclose function is blocked, and driven to AR Lockout.

3.1.8 P443 Auto-Reclose Logic Diagrams

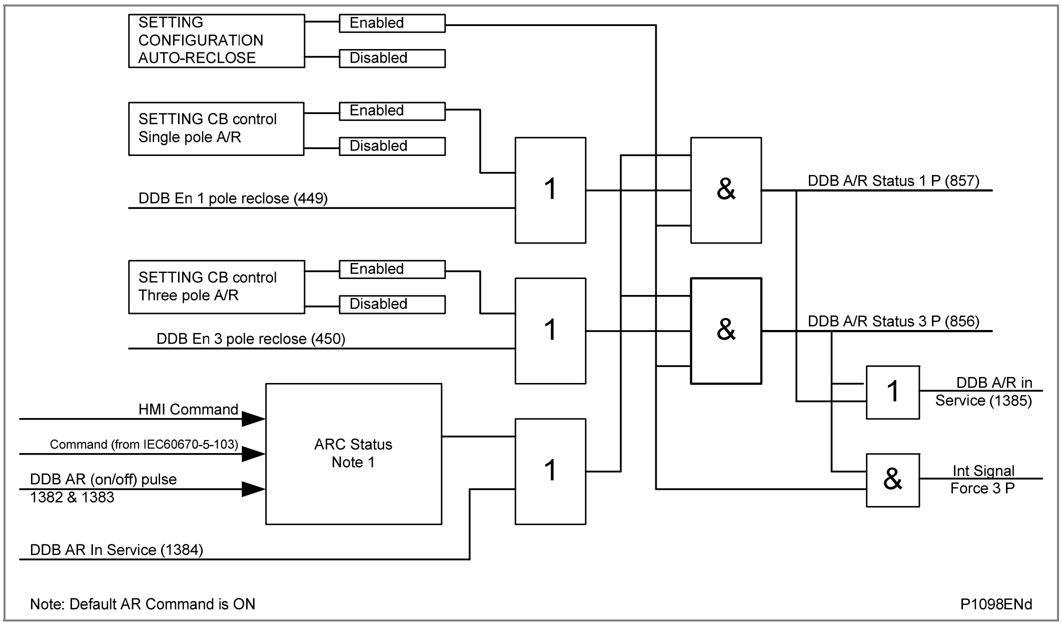

SETTING
CONFIGURATION
AUTO-RECLOSE
Enabled
Disabled
SETTING CB control
Single pole A/R
Enabled
Disabled
DDB En 1 pole reclose (449)
1
&
DDB A/R Status 1 P (857)
SETTING CB control
Three pole A/R
Enabled
Disabled
DDB En 3 pole reclose (450)
1
&
DDB A/R Status 3 P (856)
1
DDB A/R in Service (1385)
HMI Command
Command (from IEC60670-5-103)
DDB AR (on/off) pulse 1382 & 1383
ARC Status
Note 1
1
&
Int Signal Force 3 P
DDB AR In Service (1384)
Note: Default AR Command is ON
P1098ENd

Figure 87 - P443 auto-reclose enable logic

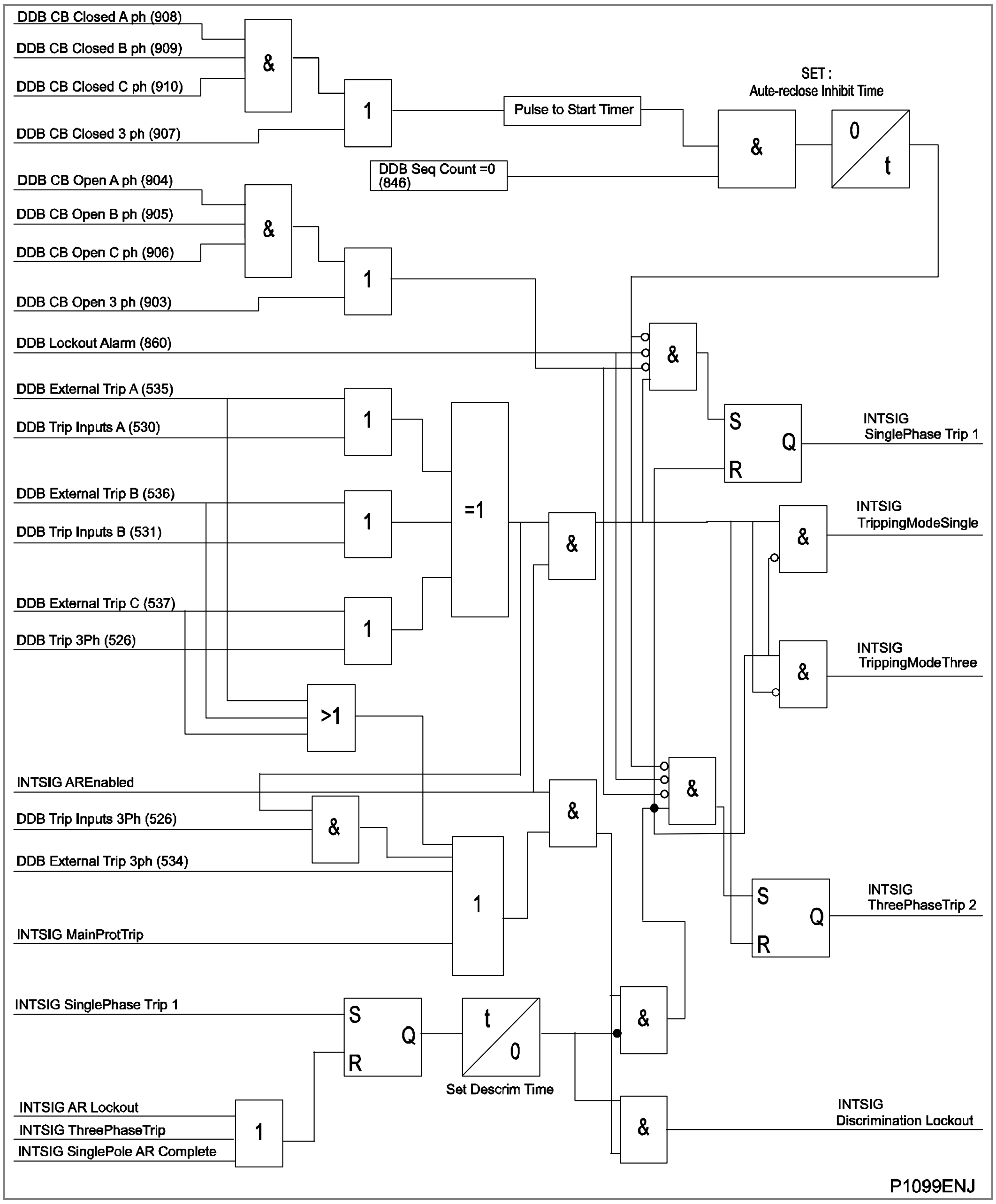

DDB CB Closed A ph (908)
DDB CB Closed B ph (909)
DDB CB Closed C ph (910)
DDB CB Closed 3 ph (907)
DDB CB Open A ph (904)
DDB CB Open B ph (905)
DDB CB Open C ph (906)
DDB CB Open 3 ph (903)
DDB Lockout Alarm (860)
DDB External Trip A (535)
DDB Trip Inputs A (530)
DDB External Trip B (536)
DDB Trip Inputs B (531)
DDB External Trip C (537)
DDB Trip 3Ph (526)
INTSIG AREnabled
DDB Trip Inputs 3Ph (526)
DDB External Trip 3ph (534)
INTSIG MainProtTrip
INTSIG SinglePhase Trip 1
INTSIG AR Lockout
INTSIG ThreePhaseTrip
INTSIG SinglePole AR Complete
&
1
Pulse to Start Timer
DDB Seq Count =0 (846)
SET : Auto-reclose Inhibit Time
0
t
=1
>1
S
Q
R
Set Descrim Time
INTSIG SinglePhase Trip 1
INTSIG TrippingModeSingle
INTSIG TrippingModeThree
INTSIG ThreePhaseTrip 2
INTSIG Discrimination Lockout
P1099ENJ

Figure 88 - P443 auto-reclose single/three pole tripping

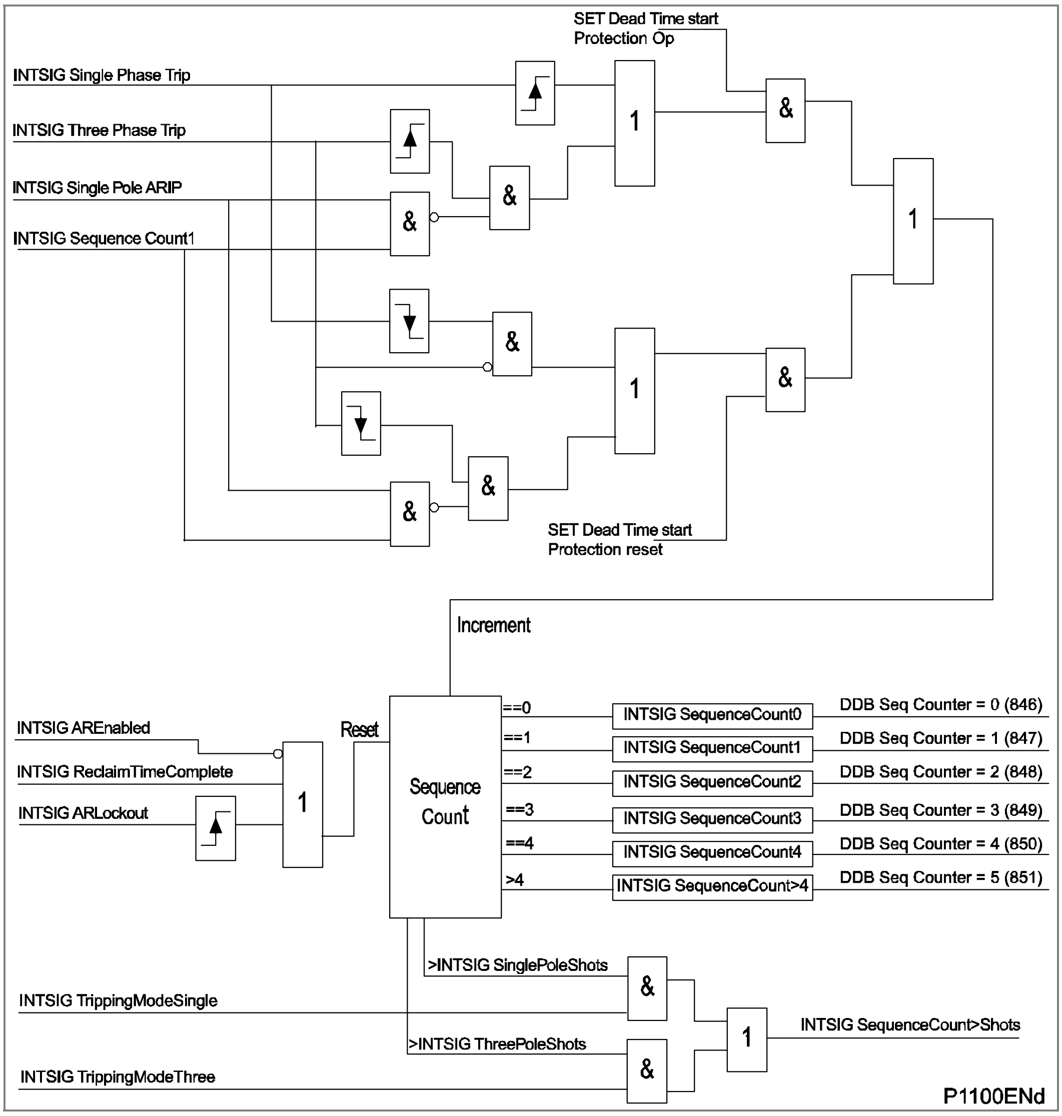

SET Dead Time start
Protection Op
INTSIG Single Phase Trip
INTSIG Three Phase Trip
INTSIG Single Pole ARIP
INTSIG Sequence Count1
SET Dead Time start
Protection reset
Increment
INTSIG AREnabled
INTSIG ReclaimTimeComplete
INTSIG ARLockout
Reset
Sequence Count
==0
==1
==2
==3
==4
>4
INTSIG SequenceCount0
INTSIG SequenceCount1
INTSIG SequenceCount2
INTSIG SequenceCount3
INTSIG SequenceCount4
INTSIG SequenceCount>4
DDB Seq Counter = 0 (846)
DDB Seq Counter = 1 (847)
DDB Seq Counter = 2 (848)
DDB Seq Counter = 3 (849)
DDB Seq Counter = 4 (850)
DDB Seq Counter = 5 (851)
>INTSIG SinglePoleShots
INTSIG TrippingModeSingle
>INTSIG ThreePoleShots
INTSIG TrippingModeThree
INTSIG SequenceCount>Shots
P1100ENd

Figure 89 - P443 auto-reclose inhibit sequence count

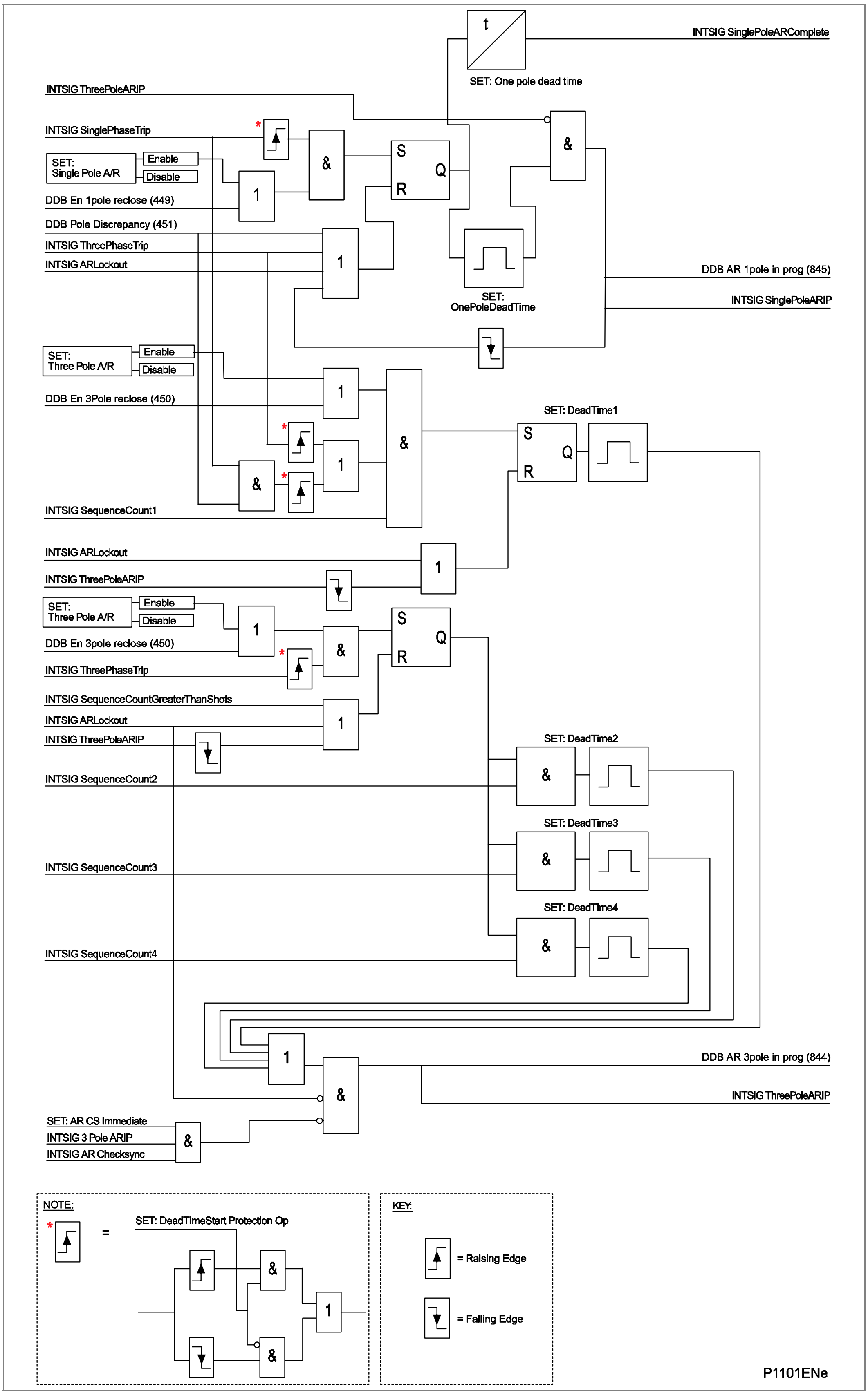

t
INTSIG SinglePoleARComplete
SET: One pole dead time
INTSIG ThreePoleARIP
INTSIG SinglePhaseTrip
*
&
S
Q
R
&
SET:
Single Pole A/R
Enable
Disable
1
DDB En 1pole reclose (449)
DDB Pole Discrepancy (451)
INTSIG ThreePhaseTrip
INTSIG ARLockout
1
SET:
OnePoleDeadTime
DDB AR 1pole in prog (845)
INTSIG SinglePoleARIP
SET:
Three Pole A/R
Enable
Disable
DDB En 3Pole reclose (450)
1
&
SET: DeadTime1
S
Q
R
*
1
&
*
INTSIG SequenceCount1
INTSIG ARLockout
1
INTSIG ThreePoleARIP
SET:
Three Pole A/R
Enable
Disable
1
S
Q
R
DDB En 3pole reclose (450)
*
&
INTSIG ThreePhaseTrip
INTSIG SequenceCountGreaterThanShots
1
INTSIG ARLockout
INTSIG ThreePoleARIP
SET: DeadTime2
&
INTSIG SequenceCount2
SET: DeadTime3
&
INTSIG SequenceCount3
SET: DeadTime4
&
INTSIG SequenceCount4
1
DDB AR 3pole in prog (844)
&
INTSIG ThreePoleARIP
SET: AR CS Immediate
INTSIG 3 Pole ARIP
INTSIG AR Checksync
&
NOTE:
*
=
SET: DeadTimeStart Protection Op
&
1
&
KEY:
= Raising Edge
= Falling Edge
P1101ENe

Figure 90 - P443 auto-reclose cycles

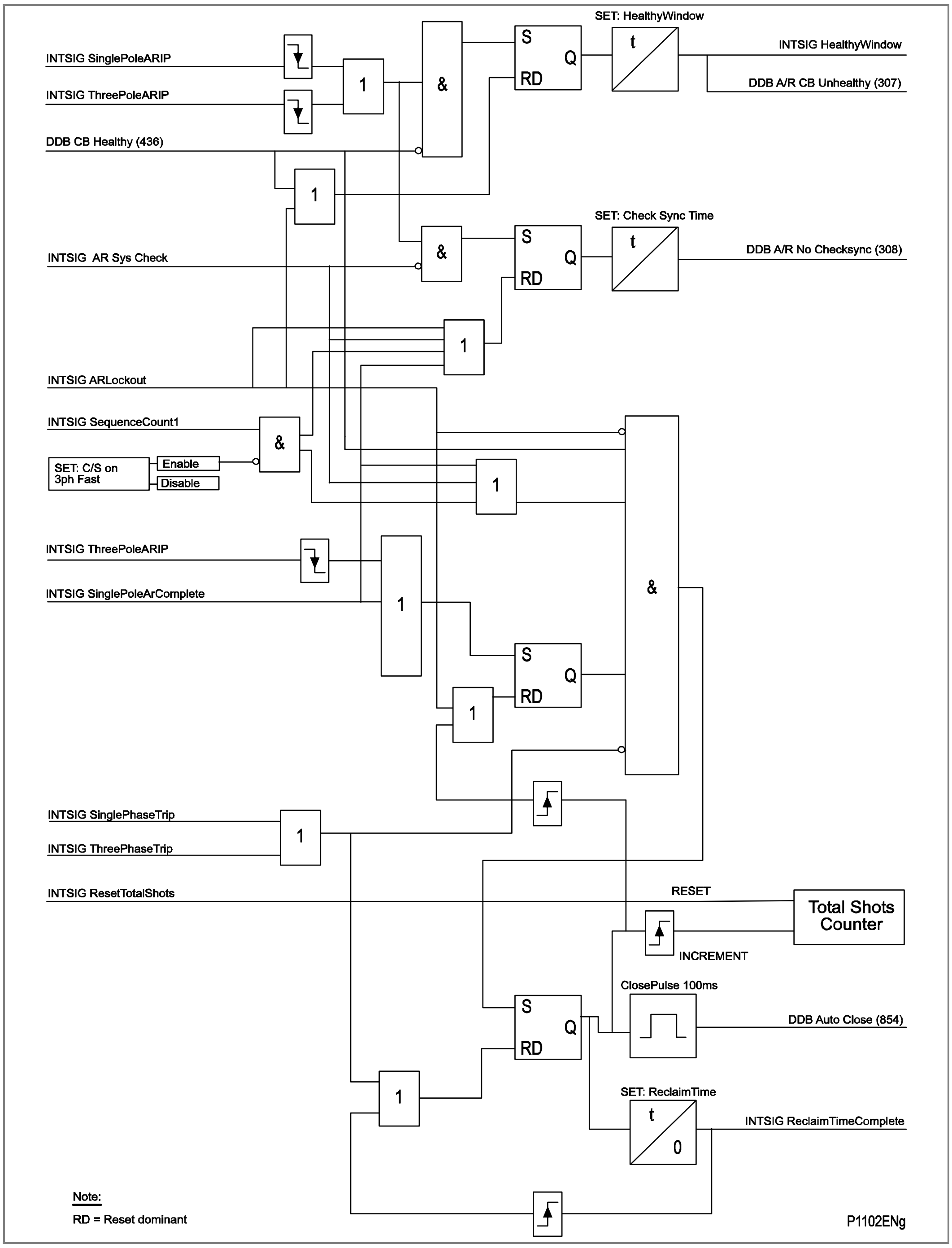

SET: HealthyWindow
INTSIG HealthyWindow
DDB A/R CB Unhealthy (307)
INTSIG SinglePoleARIP
INTSIG ThreePoleARIP
DDB CB Healthy (436)
SET: Check Sync Time
DDB A/R No Checksync (308)
INTSIG AR Sys Check
INTSIG ARLockout
INTSIG SequenceCount1
SET: C/S on 3ph Fast
Enable
Disable
INTSIG ThreePoleARIP
INTSIG SinglePoleArComplete
INTSIG SinglePhaseTrip
INTSIG ThreePhaseTrip
INTSIG ResetTotalShots
RESET
Total Shots Counter
INCREMENT
ClosePulse 100ms
DDB Auto Close (854)
SET: ReclaimTime
INTSIG ReclaimTimeComplete
S
Q
RD
t
0
&
1
Note:
RD = Reset dominant
P1102ENg

Figure 91 - P443 auto-reclose close

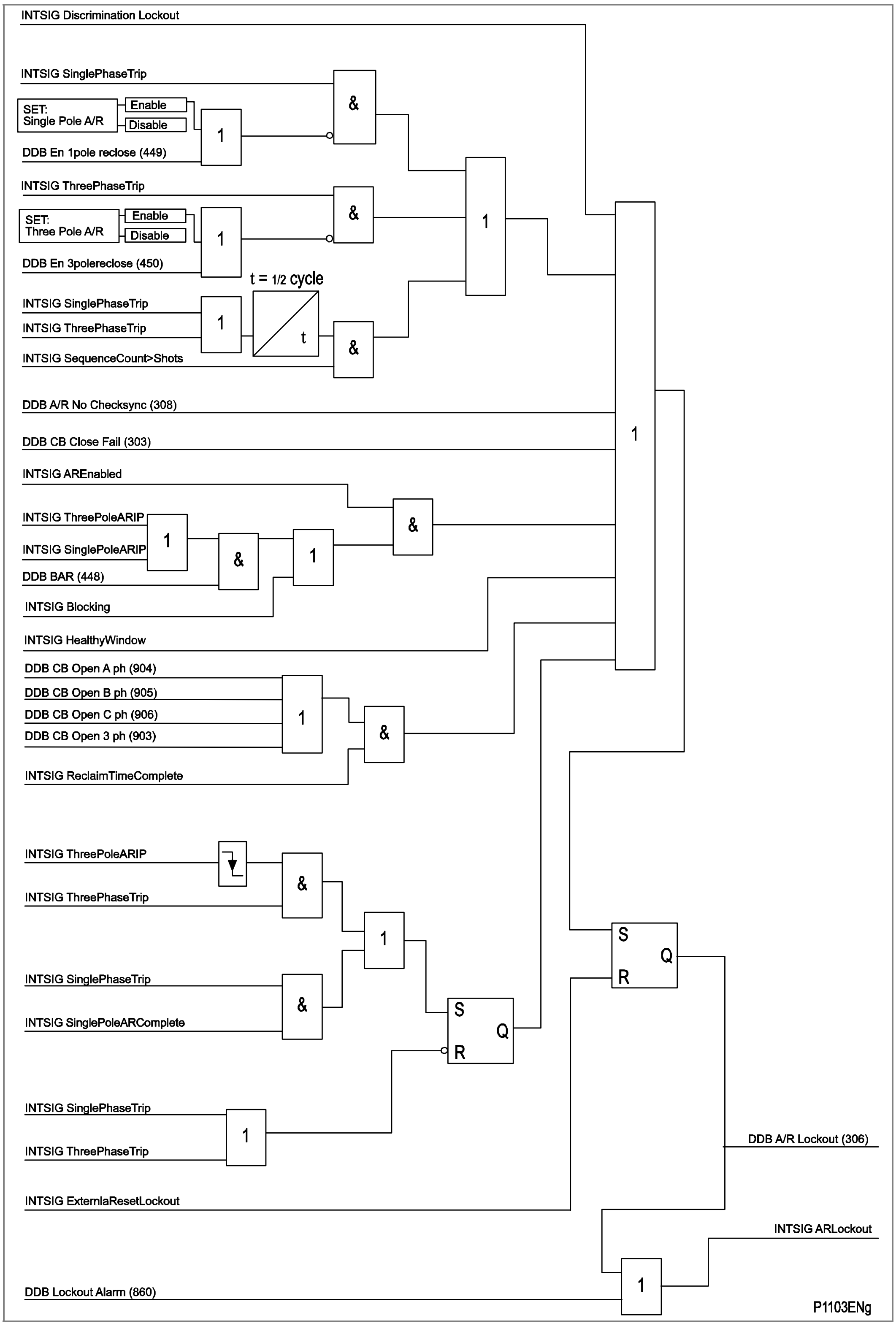

INTSIG Discrimination Lockout
INTSIG SinglePhaseTrip
SET: Single Pole A/R
Enable
Disable
DDB En 1pole reclose (449)
INTSIG ThreePhaseTrip
SET: Three Pole A/R
Enable
Disable
DDB En 3polereclose (450)
t = 1/2 cycle
INTSIG SinglePhaseTrip
INTSIG ThreePhaseTrip
t
INTSIG SequenceCount>Shots
DDB A/R No Checksync (308)
DDB CB Close Fail (303)
INTSIG AREnabled
INTSIG ThreePoleARIP
INTSIG SinglePoleARIP
DDB BAR (448)
INTSIG Blocking
INTSIG HealthyWindow
DDB CB Open A ph (904)
DDB CB Open B ph (905)
DDB CB Open C ph (906)
DDB CB Open 3 ph (903)
INTSIG ReclaimTimeComplete
INTSIG ThreePoleARIP
INTSIG ThreePhaseTrip
INTSIG SinglePhaseTrip
INTSIG SinglePoleARComplete
S
Q
R
S
Q
R
INTSIG SinglePhaseTrip
INTSIG ThreePhaseTrip
DDB A/R Lockout (306)
INTSIG ExternlaResetLockout
INTSIG ARLockout
DDB Lockout Alarm (860)
P1103ENg

Figure 92 - P443 auto-reclose lockout logic

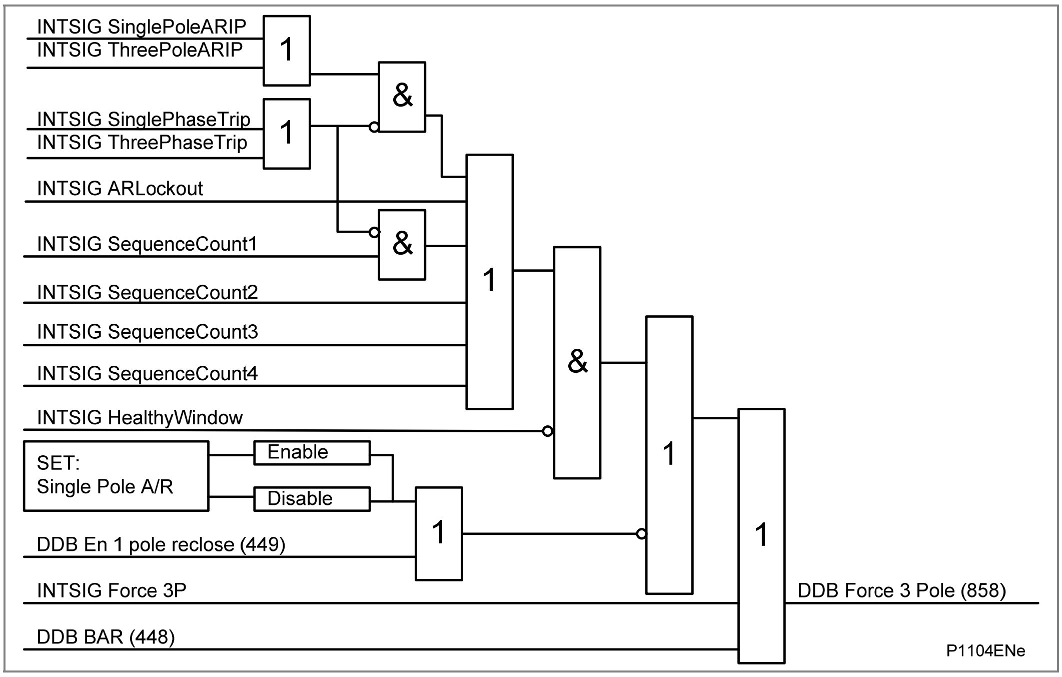

INTSIG SinglePoleARIP
INTSIG ThreePoleARIP
INTSIG SinglePhaseTrip
INTSIG ThreePhaseTrip
INTSIG ARLockout
INTSIG SequenceCount1
INTSIG SequenceCount2
INTSIG SequenceCount3
INTSIG SequenceCount4
INTSIG HealthyWindow
SET:
Single Pole A/R
Enable
Disable
DDB En 1 pole reclose (449)
INTSIG Force 3P
DDB BAR (448)
1
&
1
&
1
&
1
1
1
DDB Force 3 Pole (858)
P1104ENe

Figure 93 - P443 auto-reclose force 3 pole trip

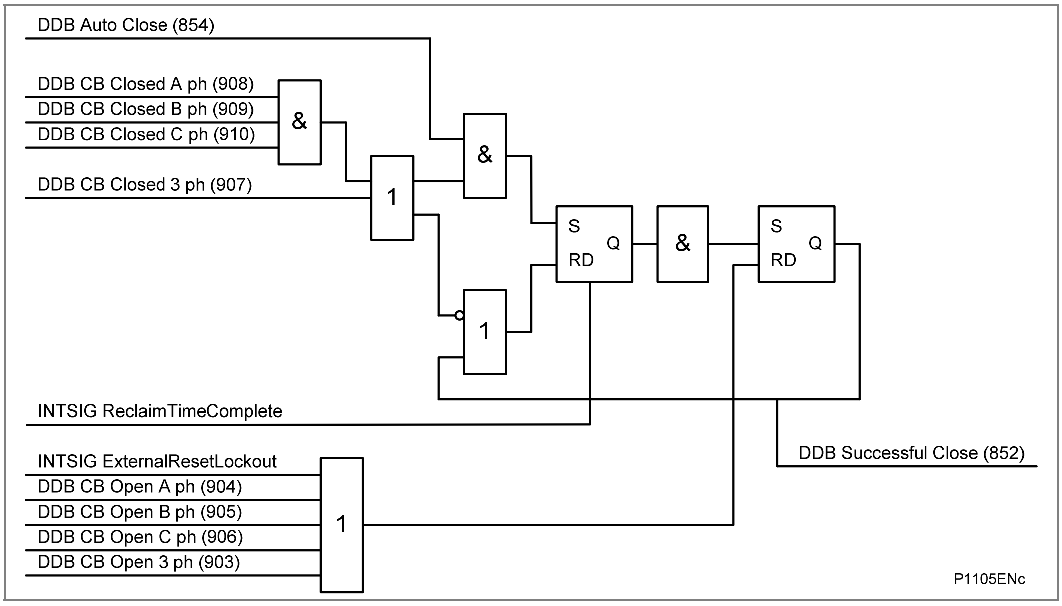

DDB Auto Close (854)
DDB CB Closed A ph (908)
DDB CB Closed B ph (909)
DDB CB Closed C ph (910)
DDB CB Closed 3 ph (907)
&
1
&
1
S
RD
Q
&
S
RD
Q
INTSIG ReclaimTimeComplete
INTSIG ExternalResetLockout
DDB CB Open A ph (904)
DDB CB Open B ph (905)
DDB CB Open C ph (906)
DDB CB Open 3 ph (903)
1
DDB Successful Close (852)
P1105ENc

Figure 94 - P443 auto-reclose close notify

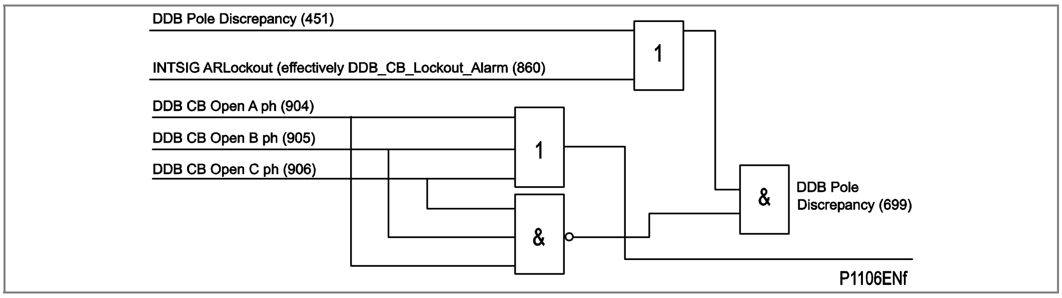

DDB Pole Discrepancy (451)
INTSIG ARLockout (effectively DDB_CB_Lockout_Alarm (860)
DDB CB Open A ph (904)
DDB CB Open B ph (905)
DDB CB Open C ph (906)
1
1
&
&
DDB Pole
Discrepancy (699)
P1106ENf

Figure 95 - P443 DDB pole discrepancy trip

3.2 P443 System Checks (including Check Synchronizer)

3.2.1 Overview

In some situations it is possible for both “**bus**” and “**line**” sides of a circuit breaker to be live when the circuit breaker is open, for example at the ends of a feeder which has a power source at each end. Therefore, when closing the circuit breaker, it is normally necessary to check that the network conditions on both sides are suitable, before giving a CB Close command. This applies to both manual circuit breaker closing and auto-reclosure. If a circuit breaker is closed when the line and bus voltages are both live, with a large phase angle, frequency or magnitude difference between them, the system could be subjected to an unacceptable shock, resulting in loss of stability, and possible damage to connected machines.

System checks involve monitoring the voltages on both sides of a circuit breaker, and, if both sides are live, performing a synchronism check to determine whether the phase angle, frequency and voltage magnitude differences between the voltage vectors, are within permitted limits.

The pre-closing system conditions for a given circuit breaker depend on the system configuration and, for auto-reclosing, on the selected auto-reclose program. For example, on a feeder with delayed auto-reclosing, the circuit breakers at the two line ends are normally arranged to close at different times. The first line end to close usually has a live bus and a dead line immediately before reclosing, and charges the line (dead line charge) when the circuit breaker closes. The second line end circuit breaker sees live bus and live line after the first circuit breaker has re-closed. If there is a parallel connection between the ends of the tripped feeder, they are unlikely to go out of synchronism, i.e. the frequencies will be the same, but the increased impedance could cause the phase angle between the two voltages to increase. Therefore the second circuit breaker to close might need a synchronism check, to ensure that the phase angle has not increased to a level which would cause unacceptable shock to the system when the circuit breaker closes.

If there are no parallel interconnections between the ends of the tripped feeder, the two systems could lose synchronism, and the frequency at one end could “**slip**” relative to the other end. In this situation, the second line end would require a synchronism check comprising both phase angle and slip frequency checks.

If the second line end busbar has no power source other than the feeder which has tripped, the circuit breaker will see a live line and dead bus assuming the first circuit breaker has re-closed. When the second line end circuit breaker closes the bus will charge from the live line (dead bus charge).

3.2.2 P443 VT Selection

The MiCOM P443 has a three phase “**Main VT**” input and a single phase “**Check Sync VT**” input. Depending on the primary system arrangement, the main three phase VT for the relay may be located on either the busbar side or the line side of the circuit breaker, with the check sync VT being located on the other side. Hence, the relay has to be programmed with the location of the main VT. This is done via the “**Main VT Location**” setting in the CT & VT RATIOS menu.

The Check Sync VT may be connected to either a phase to phase or phase to neutral voltage, and for correct synchronism check operation, the relay has to be programmed with the required connection. The “**C/S Input**” setting in the CT & VT RATIOS menu should be set to A-N, B-N, C-N, A-B, B-C or C-A A-N/1.732, B-N/1.732 or C-N/1.732 as appropriate.

3.2.3 Basic Functionality

System check logic is collectively enabled or disabled as required, by setting “**System Checks**” in the CONFIGURATION menu. The associated settings are available in SYSTEM CHECKS, sub-menus VOLTAGE MONITORS, CHECK SYNC and SYSTEM SPLIT. If “**System Checks**” is selected to Disabled, the associated SYSTEM CHECKS menu becomes invisible, and a *Sys checks Inactive* DDB signal is set.

In most situations where synchronism check is required, the Check Sync 1 function alone will provide the necessary functionality, and the Check Sync 2 and System Split signals can be ignored.

3.2.4 P443 System Check Logic Outputs

When enabled, the MiCOM P443 system check logic sets signals as listed below, according to the status of the monitored voltages.

Line Live	If the Line voltage magnitude is not less than VOLTAGE MONITORS - Live Voltage setting
Line Dead	If the Line voltage magnitude is less than VOLTAGE MONITORS - Dead Voltage setting
Bus Live	If the Bus voltage magnitude is not less than VOLTAGE MONITORS - Live Voltage setting
Bus Dead	If the Bus voltage magnitude is less than VOLTAGE MONITORS - Dead Voltage setting
Check Sync 1 OK	If Check Sync 1 Status is Enabled, the Line and Bus voltages are both live, and the parameters meet the CHECK SYNC - Check Sync 1 ---- settings
Check Sync 2 OK	If Check Sync 2 Status is Enabled, the Line and Bus voltages are both live, and the parameters meet the CHECK SYNC - Check Sync 2 ---- settings
System Split	If SS Status is Enabled, the Line and Bus voltages are both live, and the measured phase angle between the voltage vectors is greater than SYSTEM SPLIT - SS Phase Angle setting

All the above signals are available as DDB signals for mapping in Programmable Scheme Logic (PSL). In addition, the Checksync 1 & 2 signals are “**hard coded**” into the auto-reclose logic.

3.2.5 P443 Check Sync 2 and System Split

Check Sync 2 and System Split functions are included for situations where the maximum permitted slip frequency and phase angle for synchro check can change according to actual system conditions. A typical application is on a closely interconnected system, where synchronism is normally retained when a given feeder is tripped, but under some circumstances, with parallel interconnections out of service, the feeder ends can drift out of synchronism when the feeder is tripped. Depending on the system and machine characteristics, the conditions for safe circuit breaker closing could be, for example:

Condition 1: For synchronized systems, with zero or very small slip:

slip ≦50 mHz; phase angle <30°

Condition 2: For unsynchronized systems, with significant slip:

slip ≦250 mHz; phase angle <10° and decreasing

By enabling both Check Sync 1, set for condition 1, and Check Sync 2, set for condition 2, the relay can be configured to allow CB closure if either of the two conditions is detected.

For manual circuit breaker closing with synchro check, some utilities might prefer to arrange the logic to check initially for condition 1 only. However, if a System Split is detected before the condition 1 parameters are satisfied, the relay will switch to checking for condition 2 parameters instead, based upon the assumption that a significant degree of slip must be present when system split conditions are detected. This can be arranged by suitable PSL logic, using the system check DDB signals.

3.2.6 P443 Synchronism Check

Check Sync 1 and Check Sync 2 are two synchro check logic modules with similar functionality, but independent settings.

For either module to function:

The System Checks setting must be Enabled

AND

The individual Check Sync 1(2) Status setting must be Enabled

AND

The module must be individually “**enabled**”, by activation of DDB signal Check Sync 1(2) Enabled, mapped in PSL

When enabled, each logic module sets its output signal when:

Line volts and bus volts are both live (Line Live and Bus Live signals both set)

AND

Measured phase angle is < Check Sync 1(2) Phase Angle setting

AND

(For Check Sync 2 only), the phase angle magnitude is decreasing (Check Sync 1 can operate with increasing or decreasing phase angle provided other conditions are satisfied)

AND

If Check Sync 1(2) Slip Control is set to Frequency or Frequency + Timer, the measured slip frequency is < Check Sync 1(2) Slip Freq setting

AND

If Check Sync Voltage Blocking is set to OV, UV + OV, OV + DiffV or UV + OV + DiffV, both line volts and bus volts magnitudes are < Check Sync Overvoltage setting

AND

If Check Sync Voltage Blocking is set to UV, UV + OV, UV + DiffV or UV + OV + DiffV, both line volts and bus volts magnitudes are > Check Sync Undervoltage setting

AND

If Check Sync Voltage Blocking is set to DiffV, UV + DiffV, OV + DiffV or UV + OV + DiffV, the voltage magnitude difference between line volts and bus volts is < Check Sync Diff Voltage setting

AND

If Check Sync 1(2) Slip Control is set to Timer or Frequency + Timer, the above conditions have been true for a time > or = Check Sync 1(2) Slip Timer setting

Note	*Live Line/Dead Bus and Dead Bus/Line functionality is provided as part of the default PSL (see 0).*

3.2.7 P443 Slip Control by Timer

If Slip Control by Timer or Frequency + Timer is selected, the combination of Phase Angle and Timer settings determines an effective maximum slip frequency, calculated as:

$\frac{2 \times A}{T \times 360}$ Hz. for Check Sync 1

or

$\frac{A}{T \times 360}$ Hz. for Check Sync 2

Where:

A = Phase Angle setting (°)

T = Slip Timer setting (seconds)

For example, with Check Sync 1 Phase Angle setting 30° and Timer setting 3.3 sec, the “**slipping**” vector has to remain within ±30° of the reference vector for at least 3.3 seconds. Therefore a synchro check output will not be given if the slip is greater than 2 x 30° in 3.3 seconds. Using the formula: 2 x 30 ÷ (3.3 x 360) = 0.0505 Hz (50.5 mHz).

For Check Sync 2, with Phase Angle setting 10° and Timer setting 0.1 sec, the slipping vector has to remain within 10° of the reference vector, with the angle decreasing, for 0.1 sec. When the angle passes through zero and starts to increase, the synchro check output is blocked. Therefore an output will not be given if slip is greater than 10° in 0.1 second. Using the formula: 10 ÷ (0.1 x 360) = 0.278 Hz (278 mHz).

Slip control by Timer is not practical for “**large slip/small phase angle**” applications, because the timer settings required are very small, sometimes < 0.1s. For these situations, slip control by frequency is recommended.

If Slip Control by Frequency + Timer is selected, for an output to be given, the slip frequency must be less than BOTH the set Slip Freq value and the value determined by the Phase Angle and Timer settings.

3.2.8 P443 System Split

For the System Split module to function:

The System Checks setting must be Enabled.

AND

The SS Status setting must be Enabled.

AND

The module must be individually "**enabled**", by activation of DDB signal System Split Enabled, mapped in PSL.

When enabled, the System Split module sets its output signal when:

Line volts and bus volts are both live (Line Live and Bus Live signals both set).

AND

Measured phase angle is > SS Phase Angle setting.

AND

If SS Volt Blocking is set to Undervoltage, both line volts and bus volts magnitudes are > SS Undervoltage setting.

The System Split output remains set for as long as the above conditions are true, or for a minimum period equal to the SS Timer setting, whichever is longer.

The "**Check Synch**" and "**System Synch**" functionality is illustrated in Figure 96, and the logic block diagram is shown in Figure 97.

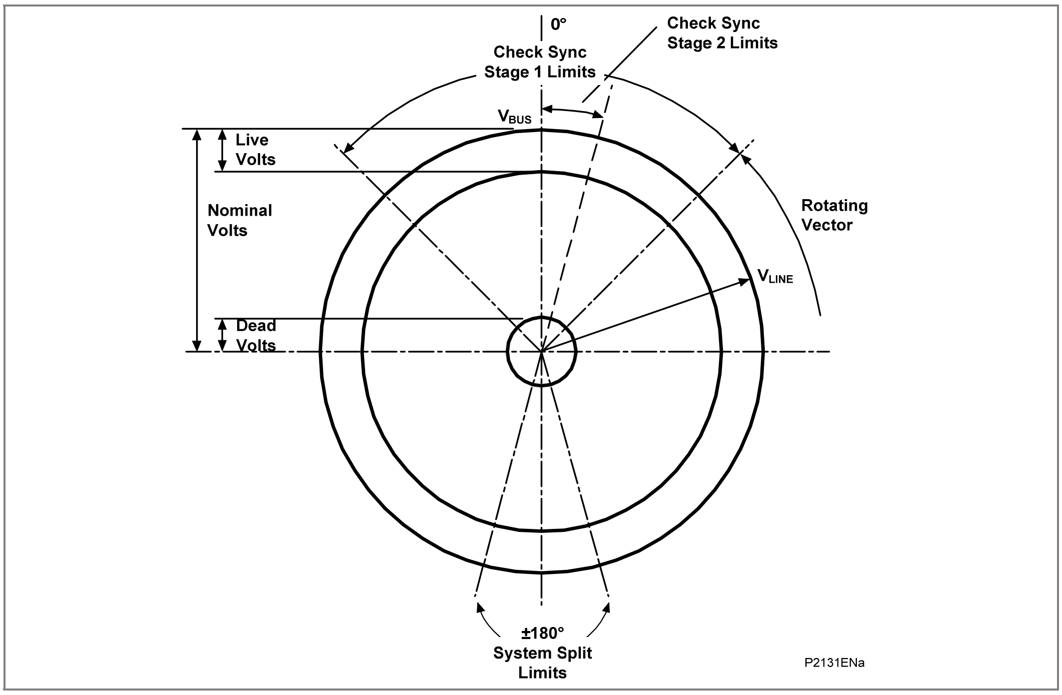

0°
Check Sync
Stage 2 Limits
Check Sync
Stage 1 Limits
V_{BUS}
Live
Volts
Nominal
Volts
Rotating
Vector
V_{LINE}
Dead
Volts
±180°
System Split
Limits
P2131ENa

Figure 96 - P443 synchro check and synchro split functionality

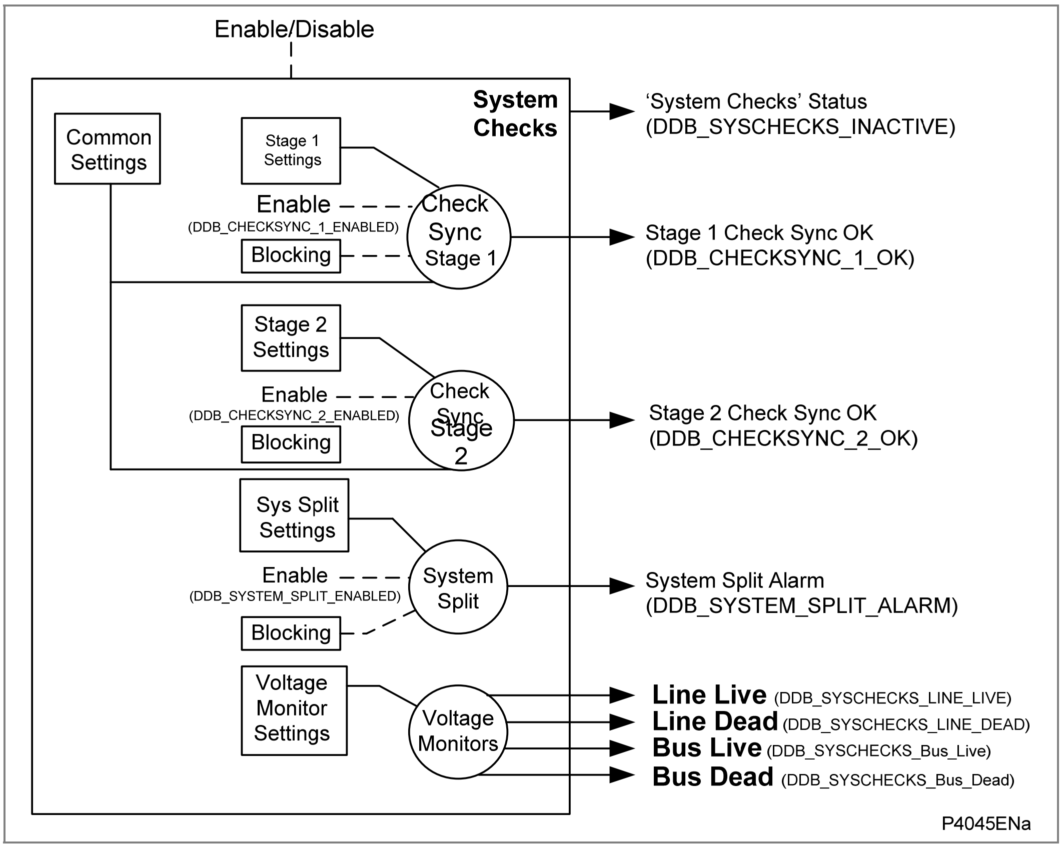

Enable/Disable
System Checks
'System Checks' Status (DDB_SYSCHECKS_INACTIVE)
Common Settings
Stage 1 Settings
Enable (DDB_CHECKSYNC_1_ENABLED)
Blocking
Check Sync Stage 1
Stage 1 Check Sync OK (DDB_CHECKSYNC_1_OK)
Stage 2 Settings
Enable (DDB_CHECKSYNC_2_ENABLED)
Blocking
Check Sync Stage 2
Stage 2 Check Sync OK (DDB_CHECKSYNC_2_OK)
Sys Split Settings
Enable (DDB_SYSTEM_SPLIT_ENABLED)
Blocking
System Split
System Split Alarm (DDB_SYSTEM_SPLIT_ALARM)
Voltage Monitor Settings
Voltage Monitors
Line Live (DDB_SYSCHECKS_LINE_LIVE)
Line Dead (DDB_SYSCHECKS_LINE_DEAD)
Bus Live (DDB_SYSCHECKS_Bus_Live)
Bus Dead (DDB_SYSCHECKS_Bus_Dead)
P4045ENa

Figure 97 - P443 check sync

3.3 P443 Auto-Reclose/Check Synchronization Interface

Output signals from the internal system check function and signals from an external system check device are combined and made available as two internal inputs to the auto-reclose function. One internal input permits auto-reclose based on system check conditions being met. The other internal input permits immediate auto-reclose based on check synchronism conditions being met, if this feature is enabled (CS AR Immediate).

Figure 98 shows the logic diagram for the interaction between the auto-reclose and system checks.

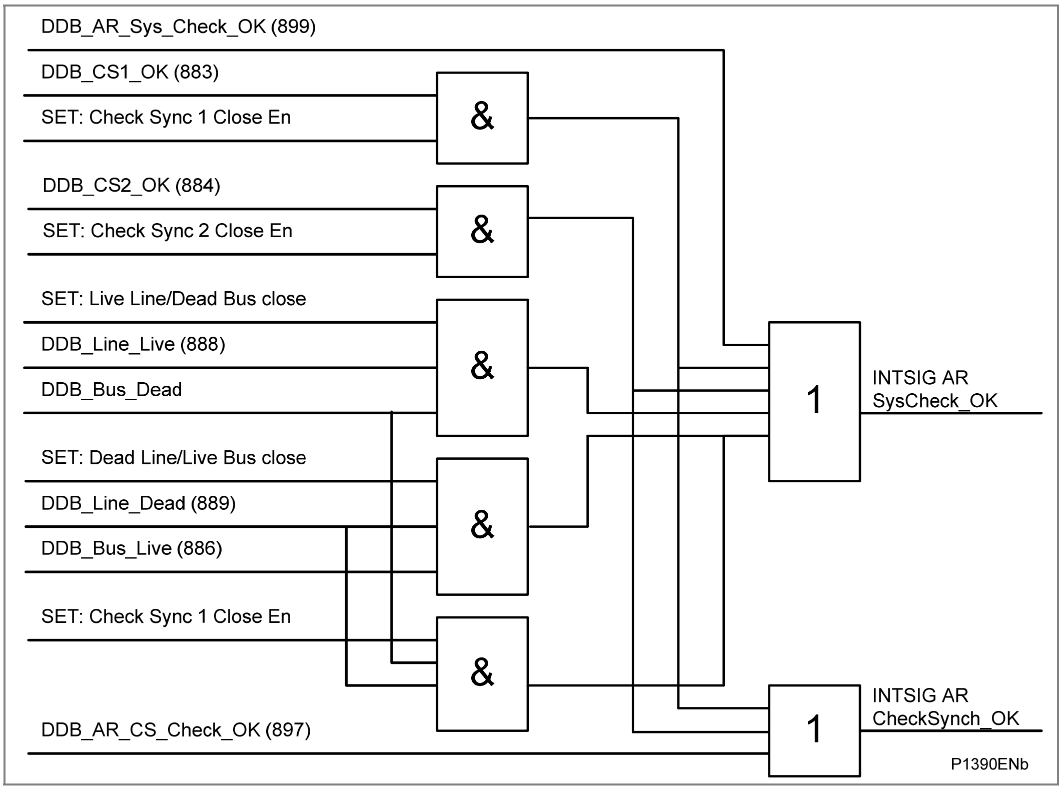

DDB_AR_Sys_Check_OK (899)
DDB_CS1_OK (883)
SET: Check Sync 1 Close En
&
DDB_CS2_OK (884)
SET: Check Sync 2 Close En
&
SET: Live Line/Dead Bus close
DDB_Line_Live (888)
DDB_Bus_Dead
&
SET: Dead Line/Live Bus close
DDB_Line_Dead (889)
DDB_Bus_Live (886)
&
SET: Check Sync 1 Close En
&
DDB_AR_CS_Check_OK (897)
1
INTSIG AR SysCheck_OK
1
INTSIG AR CheckSynch_OK
P1390ENb

Figure 98 - P443 auto-reclose/check sync interface

If an external system check device is to be used with the internal auto-reclose function then logic inputs are available for the purpose and can be assigned to opto-isolated inputs using the PSL. These logic inputs are.

- AR Check Synch OK
- AR System Check OK/SYNC

3.4 P443 Circuit Breaker State Monitoring

The relay incorporates circuit breaker state monitoring, giving an indication of the position of the circuit breaker, or, if the state is unknown, an alarm is raised.

3.4.1 P443 Circuit Breaker State Monitoring Features

MiCOM relays can be set to monitor normally open (52a) and normally closed (52b) auxiliary contacts of the circuit breaker. Under healthy conditions, these contacts will be in opposite states. Should both sets of contacts be open, this would indicate one of these conditions:

- Auxiliary contacts/wiring defective

- Circuit Breaker (CB) is defective
- CB is in isolated position

Should both sets of contacts be closed, only one of the following two conditions would apply:

- Auxiliary contacts/wiring defective
- Circuit Breaker (CB) is defective

If any of the above conditions exist, an alarm will be issued after a 5s time delay. A normally open / normally closed output contact can be assigned to this function via the programmable scheme logic (PSL). The time delay is set to avoid unwanted operation during normal switching duties.

In the CB CONTROL column of the relay menu there is a setting called '**CB Status Input**'. This cell can be set at one of the following seven options:

None	
52°	3 pole
52B	3 pole
52A & 52B	3 pole
52A	1 pole
52B	1 pole
52A & 52B	1 pole

Table 22 - CB status input options

Where '**None**' is selected no CB status will be available. This will directly affect any function within the relay that requires this signal, for example CB control, auto-reclose, etc. Where only 52A is used on its own then the relay will assume a 52B signal from the absence of the 52A signal. Circuit breaker status information will be available in this case but no discrepancy alarm will be available. The above is also true where only a 52B is used. If both 52A and 52B are used then status information will be available and in addition a discrepancy alarm will be possible, according to the following table. 52A and 52B inputs are assigned to relay opto-isolated inputs via the PSL.

Auxiliary Contact Position		CB State Detected	Action
52A	**52B**		
Open	Closed	Breaker Open	Circuit breaker healthy
Closed	Open	Breaker Closed	Circuit breaker healthy
Closed	Closed	CB Failure	Alarm raised if the condition persists for greater than 5s
Open	Open	State Unknown	Alarm raised if the condition persists for greater than 5s

Table 23 - Contact positions, states detected and actions

Where single pole tripping is used then an open breaker condition will only be given if all three phases indicate and open condition. Similarly for a closed breaker condition indication that all three phases are closed must be given. For single pole tripping applications 52A-a, 52A-b and 52A-c and/or 52B-a, 52B-b and 52B-c inputs should be used.

The CB State Monitoring Logic is shown in Figure AR 120 (Logic diagram supplement).

If inputs relevant to the circuit breaker are available to the relay via the opto isolated inputs, the logic will be able to determine the state of the circuit breaker.

3.5 P443 Circuit Breaker Condition Monitoring

Periodic maintenance of circuit breakers is necessary to ensure that the trip circuit and mechanism operate correctly, and also that the interrupting capability has not been compromised due to previous fault interruptions. Generally, such maintenance is based on a fixed time interval, or a fixed number of fault current interruptions. These methods of monitoring circuit breaker condition give a rough guide only and can lead to excessive maintenance.

3.5.1 P443 Circuit Breaker Condition Monitoring Features

For each circuit breaker trip operation the relay records statistics as shown in the following table taken from the relay menu. The menu cells shown are counter values only. The Min./Max. values in this case show the range of the counter values. These cells can not be set.

Menu Text	Default	Setting		Step Size
		Min.	Max.	
CB Operations {3 pole tripping}	0	0	10000	1
Displays the total number of 3 pole trips issued by the relay.				
Total IA Broken	0	0	25000In^	1
Displays the total fault current interrupted by the relay for the A phase.				
Total IB Broken	0	0	25000In^	1
Displays the total fault current interrupted by the relay for the A phase.				
Total IC Broken	0	0	25000In^	1In^
Displays the total fault current interrupted by the relay for the A phase.				
CB Operate Time	0	0	0.5s	0.001
Displays the calculated CB operating time.				
Reset CB Data	No		Yes, No	
Reset the CB condition counters.				

Table 24 - CB operations Min/Max values

The above counters may be reset to zero, for example, following a maintenance inspection and overhaul. The circuit breaker condition monitoring counters will be updated every time the relay issues a trip command. In cases where the breaker is tripped by an external protection device it is also possible to update the CB condition monitoring. This is achieved by allocating one of the relays opto-isolated inputs (via the programmable scheme logic) to accept a trigger from an external device. The signal that is mapped to the opto is called '**External Trip**'.

Note	*When in Commissioning test mode the CB condition monitoring counters will not be updated.*

The measurement of circuit breaker broken current operating time and the overall CB Monitoring logic diagram, now follow as Figure 99, Figure 100 and Figure 101.

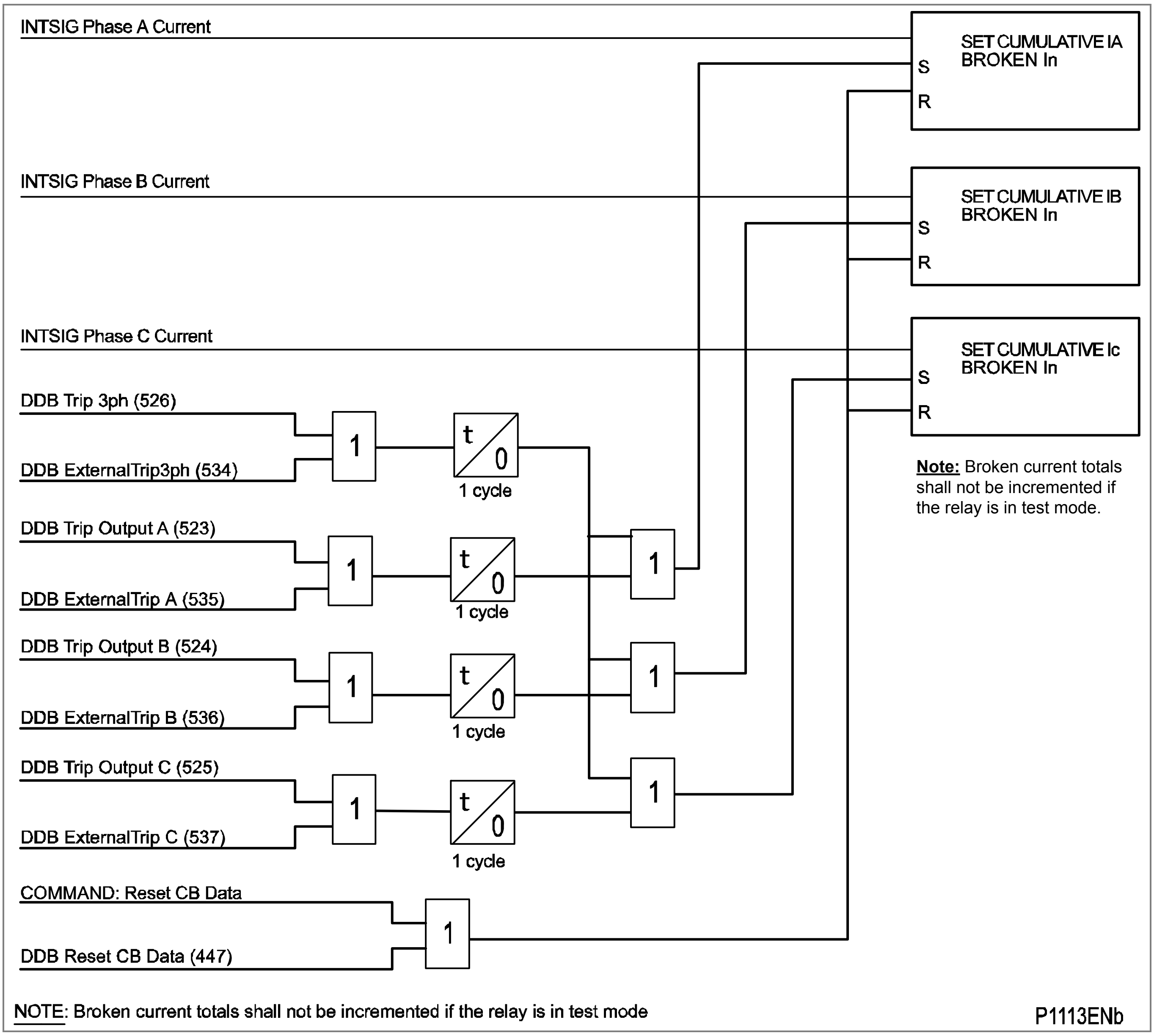

INTSIG Phase A Current
INTSIG Phase B Current
INTSIG Phase C Current
DDB Trip 3ph (526)
DDB ExternalTrip3ph (534)
DDB Trip Output A (523)
DDB ExternalTrip A (535)
DDB Trip Output B (524)
DDB ExternalTrip B (536)
DDB Trip Output C (525)
DDB ExternalTrip C (537)
COMMAND: Reset CB Data
DDB Reset CB Data (447)
1
t
0
1 cycle
S
R
SET CUMULATIVE IA BROKEN In
SET CUMULATIVE IB BROKEN In
SET CUMULATIVE Ic BROKEN In
Note: Broken current totals shall not be incremented if the relay is in test mode.
NOTE: Broken current totals shall not be incremented if the relay is in test mode
P1113ENb

Figure 99 - P443 circuit breaker condition monitoring - broken current

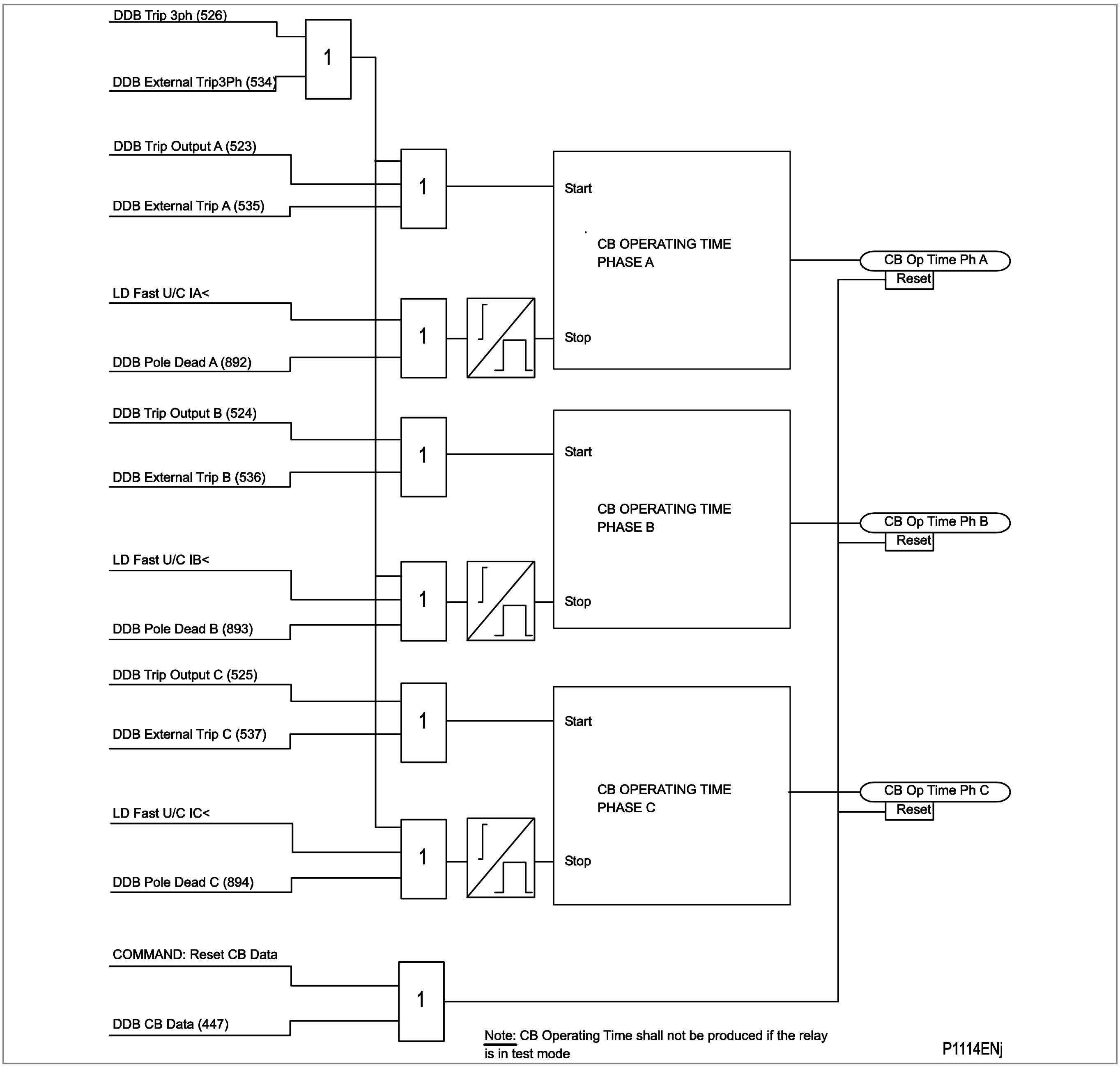

DDB Trip 3ph (526)
DDB External Trip3Ph (534)
DDB Trip Output A (523)
DDB External Trip A (535)
LD Fast U/C IA<
DDB Pole Dead A (892)
DDB Trip Output B (524)
DDB External Trip B (536)
LD Fast U/C IB<
DDB Pole Dead B (893)
DDB Trip Output C (525)
DDB External Trip C (537)
LD Fast U/C IC<
DDB Pole Dead C (894)
COMMAND: Reset CB Data
DDB CB Data (447)
1
Start
Stop
CB OPERATING TIME PHASE A
CB OPERATING TIME PHASE B
CB OPERATING TIME PHASE C
CB Op Time Ph A
CB Op Time Ph B
CB Op Time Ph C
Reset
Note: CB Operating Time shall not be produced if the relay is in test mode
P1114ENj

Figure 100 - P443 circuit breaker condition monitoring - operation time

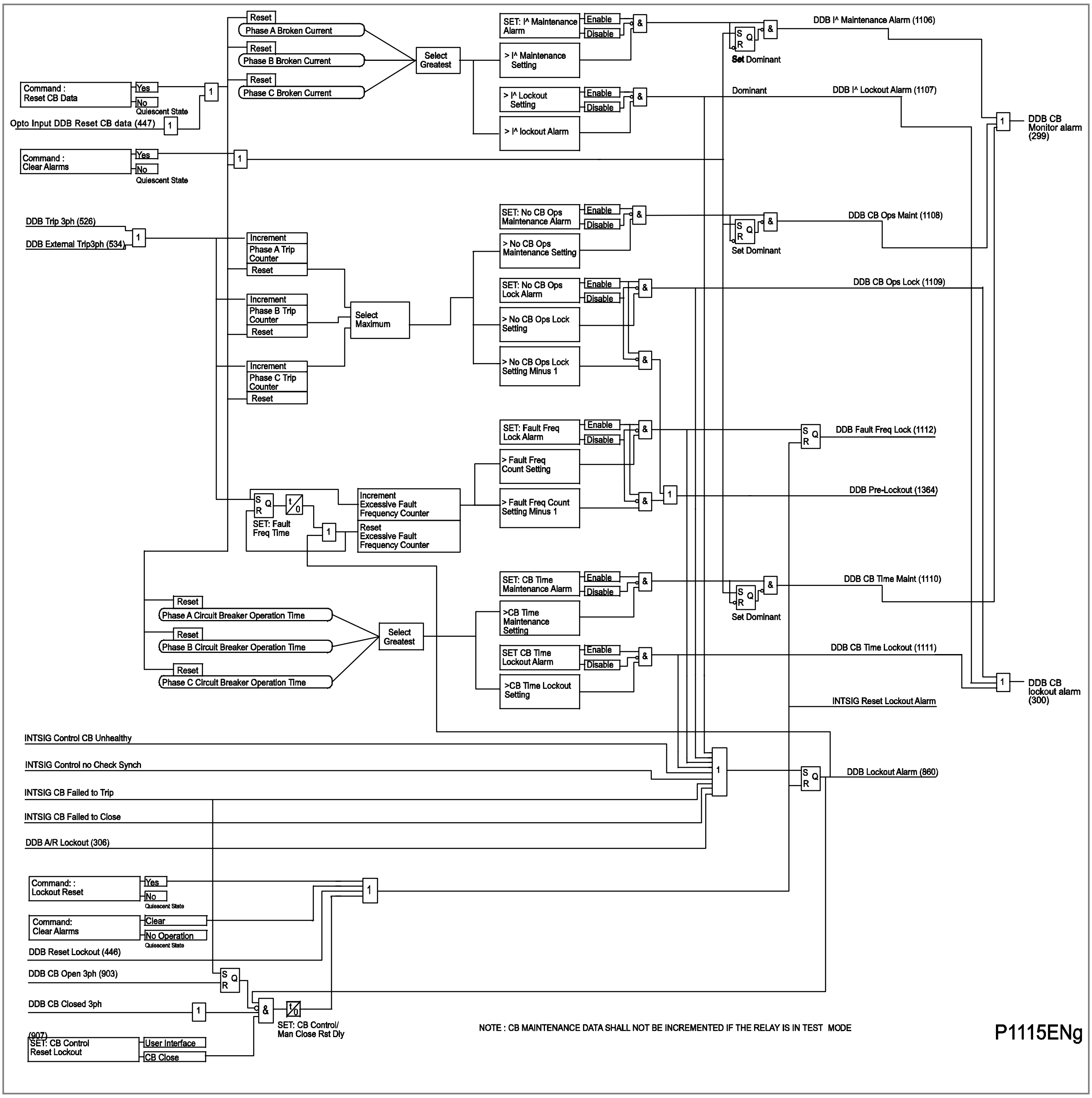

Reset
Phase A Broken Current
Reset
Phase B Broken Current
Reset
Phase C Broken Current
Select Greatest
SET: I^ Maintenance Alarm
Enable
Disable
&
> I^ Maintenance Setting
> I^ Lockout Setting
Enable
Disable
&
> I^ lockout Alarm
S Q R
&
Set Dominant
DDB I^ Maintenance Alarm (1106)
Dominant
DDB I^ Lockout Alarm (1107)
1
DDB CB Monitor alarm (299)
Command : Reset CB Data
Yes
No
Quiescent State
1
Opto Input DDB Reset CB data (447)
1
Command : Clear Alarms
Yes
No
Quiescent State
1
DDB Trip 3ph (526)
DDB External Trip3ph (534)
1
Increment
Phase A Trip Counter
Reset
Increment
Phase B Trip Counter
Reset
Increment
Phase C Trip Counter
Reset
Select Maximum
SET: No CB Ops Maintenance Alarm
Enable
Disable
&
> No CB Ops Maintenance Setting
S Q R
&
Set Dominant
DDB CB Ops Maint (1108)
SET: No CB Ops Lock Alarm
Enable
Disable
&
DDB CB Ops Lock (1109)
> No CB Ops Lock Setting
> No CB Ops Lock Setting Minus 1
&
SET: Fault Freq Lock Alarm
Enable
Disable
&
> Fault Freq Count Setting
S Q R
DDB Fault Freq Lock (1112)
> Fault Freq Count Setting Minus 1
&
1
DDB Pre-Lockout (1364)
S Q R
t 0
SET: Fault Freq Time
1
Increment Excessive Fault Frequency Counter
Reset Excessive Fault Frequency Counter
SET: CB Time Maintenance Alarm
Enable
Disable
&
S Q R
&
Set Dominant
DDB CB Time Maint (1110)
>CB Time Maintenance Setting
SET CB Time Lockout Alarm
Enable
Disable
&
DDB CB Time Lockout (1111)
>CB Time Lockout Setting
1
DDB CB lockout alarm (300)
INTSIG Reset Lockout Alarm
Reset
Phase A Circuit Breaker Operation Time
Reset
Phase B Circuit Breaker Operation Time
Reset
Phase C Circuit Breaker Operation Time
Select Greatest
INTSIG Control CB Unhealthy
INTSIG Control no Check Synch
INTSIG CB Failed to Trip
INTSIG CB Failed to Close
DDB A/R Lockout (306)
1
S Q R
DDB Lockout Alarm (860)
Command: : Lockout Reset
Yes
No
Quiescent State
Command: Clear Alarms
Clear
No Operation
Quiescent State
DDB Reset Lockout (446)
1
DDB CB Open 3ph (903)
S Q R
DDB CB Closed 3ph
(907)
1
&
t 0
SET: CB Control/ Man Close Rst Dly
SET: CB Control Reset Lockout
User Interface
CB Close
NOTE : CB MAINTENANCE DATA SHALL NOT BE INCREMENTED IF THE RELAY IS IN TEST MODE
P1115ENg

Figure 101 - P443 CB monitoring

3.6 P443 Circuit Breaker Control

The relay includes the following options for control of a single circuit breaker:

- Local tripping and closing, via the relay menu or *Hotkeys*
- Local tripping and closing, via relay opto-isolated inputs
- Remote tripping and closing, using the relay communications

It is recommended that separate relay output contacts are allocated for remote circuit breaker control and protection tripping. This enables the control outputs to be selected via a local/remote selector switch as shown in Figure 102. Where this feature is not required the same output contact(s) can be used for both protection and remote tripping.

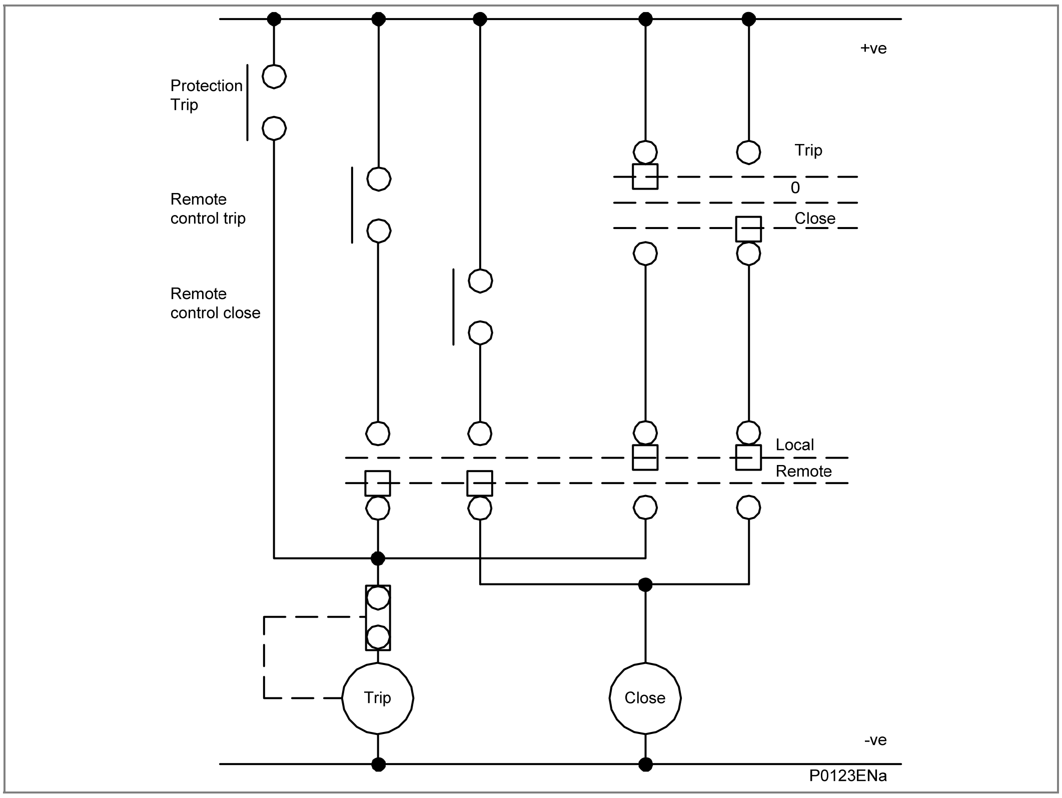


Figure 102 - Remote control of circuit breaker

A manual trip will be permitted provided that the circuit breaker is initially closed. Likewise, a close command can only be issued if the CB is initially open. To confirm these states it will be necessary to use the breaker 52A and/or 52B contacts (the different selection options are given from the '**CB Status Input**' cell above). If no CB auxiliary contacts are available then this cell should be set to None. Under these circumstances no CB control (manual or auto) will be possible.

A circuit breaker close command "**CB Close**" will initiate closing of the circuit breaker. The output contact, however, can be set to operate following a user defined time delay ('**Man Close Delay**'). This is designed to give personnel time to retreat from the circuit breaker following the close command. This time delay applies to all manual circuit breaker close commands.

The control close cycle can be cancelled at any time before the output contact operates by any appropriate trip signal, or by activating DDB (443) "**Reset Close Delay**".

An "**Auto Close CB**" signal from the "**Auto close**" logic bypasses the "**Man Close Delay**" time, and the "**CB Close**" output operate immediately to close the circuit breaker.

The length of the trip or close control pulse can be set via the '**Trip Pulse Time**' and '**Close Pulse Time**' settings respectively. These should be set long enough to ensure the breaker has completed its open or close cycle before the pulse has elapsed.

Note	*The manual trip and close commands are found in the SYSTEM DATA column and the hotkey menu.*

If an attempt to close the breaker is being made, and a protection trip signal is generated, the protection trip command overrides the close command.

Where the check synchronism function is set, this can be enabled to supervise manual circuit breaker close commands. A circuit breaker close output will only be issued if the check synchronism criteria are satisfied. A user settable time delay is included ('**C/S Window**') for manual closure with check synchronizing. If the checksynch criteria are not satisfied in this time period following a close command the relay will lockout and alarm.

In addition to a synchronism check before manual reclosure there is also a CB Healthy check if required. This facility accepts an input to one of the relays opto-isolators to indicate that the breaker is capable of closing (circuit breaker energy for example). A user settable time delay is included ('**Healthy Window**') for manual closure with this check. If the CB does not indicate a healthy condition in this time period following a close command then the relay will lockout and alarm.

Where auto-reclose is used it may be desirable to block its operation when performing a manual close. In general, the majority of faults following a manual closure will be permanent faults and it will be undesirable to auto-reclose.

The '**AR Inhibit Time**' setting can be used to prevent auto-reclose being initiated when the CB is manually closed onto a fault. Auto-reclose is disabled for the AR Inhibit Time following manual CB closure.

If the CB fails to respond to the control command (indicated by no change in the state of CB Status inputs) a '**CB Failed to Trip**' or '**CB Failed to Close**' alarm will be generated after the relevant trip or close pulses have expired. These alarms can be viewed on the relay LCD display, remotely via the relay communications, or can be assigned to operate output contacts for annunciation using the relays Programmable Scheme Logic (PSL).

Note	*The '**Healthy Window**' timer and '**C/S Window**' timer set under this menu section are applicable to manual circuit breaker operations only. These settings are duplicated in the Auto-reclose menu for Auto-reclose applications.*

The 'Lockout Reset' and 'Reset Lockout by' setting cells in the menu are applicable to CB Lockouts associated with manual circuit breaker closure, CB Condition monitoring (Number of circuit breaker operations, for example) and auto-reclose lockouts.

The CB Control Logic is illustrated in Figure 103.

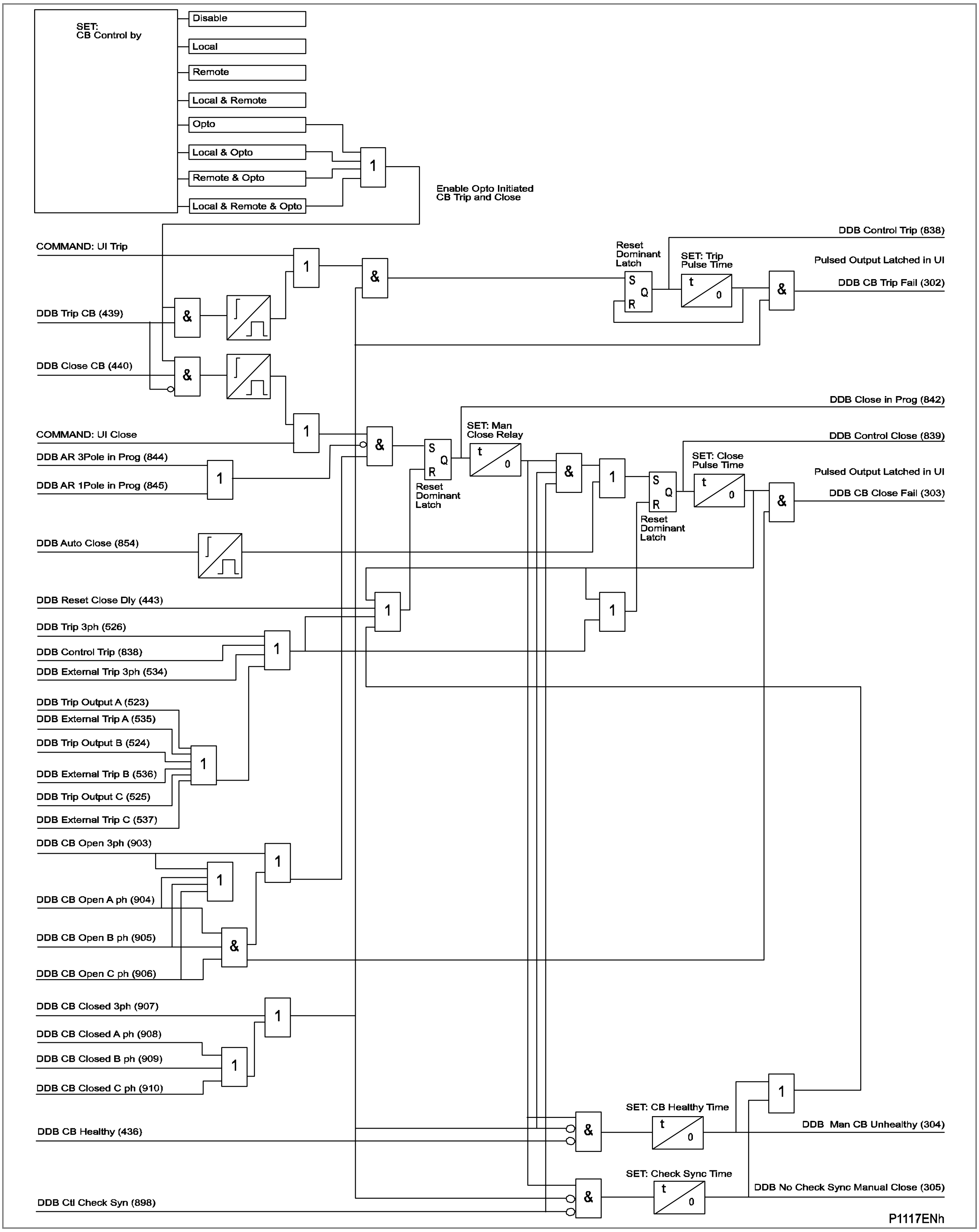

SET:
CB Control by
Disable
Local
Remote
Local & Remote
Opto
Local & Opto
Remote & Opto
Local & Remote & Opto
Enable Opto Initiated
CB Trip and Close
COMMAND: UI Trip
DDB Trip CB (439)
DDB Close CB (440)
COMMAND: UI Close
DDB AR 3Pole in Prog (844)
DDB AR 1Pole in Prog (845)
DDB Auto Close (854)
DDB Reset Close Dly (443)
DDB Trip 3ph (526)
DDB Control Trip (838)
DDB External Trip 3ph (534)
DDB Trip Output A (523)
DDB External Trip A (535)
DDB Trip Output B (524)
DDB External Trip B (536)
DDB Trip Output C (525)
DDB External Trip C (537)
DDB CB Open 3ph (903)
DDB CB Open A ph (904)
DDB CB Open B ph (905)
DDB CB Open C ph (906)
DDB CB Closed 3ph (907)
DDB CB Closed A ph (908)
DDB CB Closed B ph (909)
DDB CB Closed C ph (910)
DDB CB Healthy (436)
DDB Ctl Check Syn (898)
Reset
Dominant
Latch
SET: Trip
Pulse Time
DDB Control Trip (838)
Pulsed Output Latched in UI
DDB CB Trip Fail (302)
DDB Close in Prog (842)
SET: Man
Close Relay
DDB Control Close (839)
SET: Close
Pulse Time
Pulsed Output Latched in UI
DDB CB Close Fail (303)
SET: CB Healthy Time
DDB Man CB Unhealthy (304)
SET: Check Sync Time
DDB No Check Sync Manual Close (305)
P1117ENh

Figure 103 - P443 circuit breaker control

3.6.1 CB Control using Hotkeys

The hotkeys allow direct access to manual trip and close commands without the need to enter the SYSTEM DATA column. Red or green color coding can be applied when used in CB control applications.

IF <<TRIP>> or <<CLOSE>> is selected the user is prompted to confirm the execution of the relevant command. If a trip is executed a screen with the CB status will be displayed once the command has been completed. If a close is executed a screen with a timing bar will appear while the command is being executed. This screen has the option to cancel or restart the close procedure. The timer used is taken from the manual close delay timer setting in the CB Control menu. When the command has been executed, a screen confirming the present status of the circuit breaker is displayed. The user is then prompted to select the next appropriate command or exit - this will return to the default relay screen.

If no keys are pressed for a period of 25 seconds while waiting for the command confirmation, the relay will revert to showing the CB Status. If no key presses are made for a period of 25 seconds while displaying the CB status screen, the relay will revert to the default relay screen. Figure 104 shows the hotkey menu associated with CB control functionality.

To avoid accidental operation of the trip and close functionality, the hotkey CB control commands will be disabled for 10 seconds after exiting the hotkey menu.

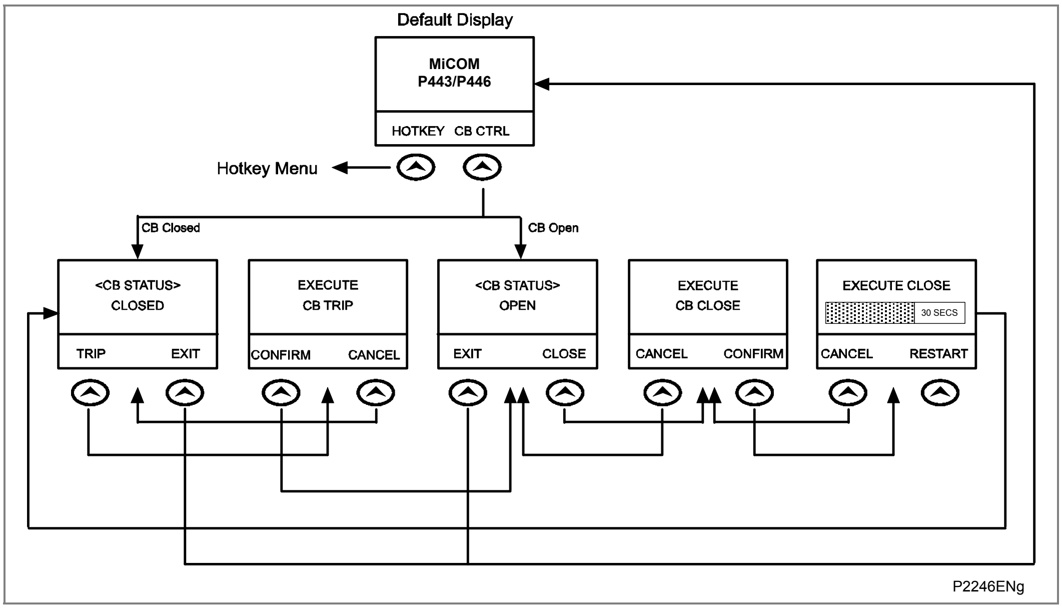

Default Display
MiCOM
P443/P446
HOTKEY CB CTRL
Hotkey Menu
CB Closed
CB Open
<CB STATUS>
CLOSED
TRIP
EXIT
EXECUTE
CB TRIP
CONFIRM
CANCEL
<CB STATUS>
OPEN
EXIT
CLOSE
EXECUTE
CB CLOSE
CANCEL
CONFIRM
EXECUTE CLOSE
30 SECS
CANCEL
RESTART
P2246ENg

Figure 104 - CB control hotkey menu

3.6.2 CB Control using Function Keys

The function keys allow direct control of the circuit breaker if programmed to do this in PSL. local tripping and closing, via relay opto-isolated inputs must be set in the "**CB Control**" menu '**CB control by**' cell to enable this functionality. All CB manual control settings and conditions will apply for manual tripping and closing via function keys.

The following default logic can be programmed to activate this feature:

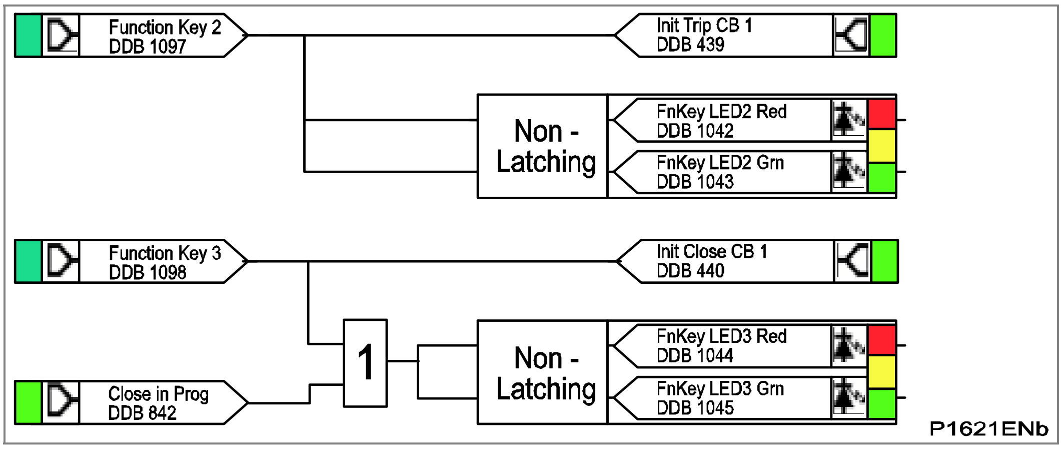

Function Key 2
DDB 1097
Init Trip CB 1
DDB 439
Non - Latching
FnKey LED2 Red
DDB 1042
FnKey LED2 Grn
DDB 1043
Function Key 3
DDB 1098
Init Close CB 1
DDB 440
1
Close in Prog
DDB 842
Non - Latching
FnKey LED3 Red
DDB 1044
FnKey LED3 Grn
DDB 1045
P1621ENb

Figure 105 - CB control via function keys default PSL

Function key 2 and function key 3 are both enabled and set to '**Normal**' Mode and the associated DDB signals '**DDB 1097**' and '**DDB 1098**' will be active high '**1**' on key press.

The following DDB signal must be mapped to the relevant function key:

Trip CB	(DDB 439) - Initiate manual circuit breaker trip
Close CB	(DDB 440) - Initiate manual circuit breaker close

The programmable function key LED's have been mapped such that the LED's will indicate yellow whilst the keys are activated.

4 DUAL CB CONTROL: P446 OPERATIONAL DESCRIPTION

This section describes the P446 operational control of dual circuit breakers.

4.1 Introduction

The circuit breaker control and monitoring in the dual-breaker P446 provides single phase or three phase switching of a feeder controlled by two circuit breakers at a line end, for example in a one and a half switch configuration or at a mesh type (ring bus) installation. It can also be set to manage switching of a feeder controlled by a single circuit breaker

This section introduces the operation of the circuit breaker scheme. It describes the circuit breaker state monitoring, condition monitoring, circuit breaker control, and the circuit breaker auto-reclose operation.

The control of dual circuit breaker switching sequences represents a complex logic arrangement. The operation is best understood by reference to the design logic diagrams that have been used to implement the functionality. For ease of reference, all these logic diagrams have been put together in a supplementary section "**P446 Circuit Breaker Control and Auto-Reclose Figures**" section (AR figures) at the end of this section. Any figures that are not explicitly presented in this section will be found in the AR figures section and will be clearly indicated.

The inputs and outputs of the logic described are, in many cases, DDB signals that are available to the Programmable Scheme Logic (PSL). A description of these signals can be found in the Programmable Logic section (P44y/EN PL) of this manual. Other signals are also used to define the operation but are internal to the logic of the circuit breaker control. Unlike the DDB signals, these internal signals cannot be accessed using the programmable scheme logic. They are hard-coded into the application software. A second supplementary section lists these signals and provides a brief description to aid understanding.

4.2 P446 CB Scheme Designation

In the dual-breaker P446, the two controlled circuit breakers are designated CB1 and CB2. CB1 connects the P446 to Bus1 and CB2 connects the P446 to Bus 2.

It is possible to configure the P446 for use in a single circuit breaker application using either CB1 control or CB2 control. If operating like this, all text, etc., associated with the unused circuit breaker is hidden.

Note	In some of the menu text, the reference to which circuit breaker is being described, is not explicitly stated (for example, "**CB Operations**" in the circuit breaker monitoring features). **In all such cases, an unqualified "CB" reference should be assumed to be associated with CB1.** "**CB2**" is always used to explicitly indicate CB2. An unqualified "**CB**" or an explicit "**CB1**" refers to CB1. CBx indicates either CB1 or CB2.

4.3 P446 CB Status

For each circuit breaker, the P446 incorporates circuit breaker state monitoring, giving an indication of the position of each circuit breaker or, if the state is unknown, an alarm is raised.

The P446 can be set to monitor normally open (52A) and normally closed (52B) auxiliary contacts of each circuit breaker. For each circuit breaker, under healthy conditions, the 52A and 52B contacts should be in opposite states. Should both sets of contacts be open, this would indicate one of the following conditions:

- Auxiliary contacts/wiring defective
- Circuit breaker is defective
- Circuit breaker is in an isolated position

Should both sets of contacts be closed, only one of the following two conditions would apply:

- Auxiliary contacts/wiring defective
- Circuit breaker is defective

If any of the above conditions exist, an alarm will be issued after time delay as set in “**CB Status time**” in the CB CONTROL settings column of the menu. A normally open/normally closed output contact can be assigned to this function via the programmable scheme logic (PSL). The time delay is set to avoid unwanted operation during normal switching duties where fleeting abnormal circuit breaker status conditions may exist as the contacts change state.

Note	*The “**CB Status time**” setting is one setting applied equally to both controlled circuit breakers.*

In the CB CONTROL column of the relay menu there are two settings: “**CB1 Status Input**” and “**CB2 Status Input**”. Each cell can be set at one of the following seven options to control CB1 and/or CB2:

- None
- 52A 3 pole
- 52B 3 pole
- 52A & 52B 3 pole
- 52A 1 pole
- 52B 1 pole
- 52A & 52B 1 pole

If “**None**” is selected, no circuit breaker status will be available. This will directly affect any function within the relay that requires this signal, for example circuit breaker control, auto-reclose, etc..

Where only “**52A**” (open when the circuit breaker is open, closed when the circuit breaker is closed) is used then the relay will assume a “**52B**” signal from the absence of the “**52A**” signal. Circuit breaker status information will be available in this case but no discrepancy alarm will be available. The above is also true where only a “**52B**” (closed when the circuit breaker is open, open when the circuit breaker is closed) is used.

If both “**52A**” and “**52B**” are used then status information will be available and in addition a discrepancy alarm “**CBx Status Alarm**” (x = 1 or 2) will be possible, according to the following table. “**52A**” and “**52B**” inputs are assigned to relay opto-isolated inputs via the PSL.

Auxiliary contact position		CB State Detected	Action
52A	**52B**		
Open	Closed	Breaker Open	Circuit breaker healthy
Closed	Open	Breaker Closed	Circuit breaker healthy
Closed	Closed	CB Failure	Alarm raised if the condition persists for greater than “CB Status time”
Open	Open	State Unknown	Alarm raised if the condition persists for greater than “CB Status time”

Table 25 - Auxiliary contact positions, CB State Detected and actions

In the internal logic of the P446, the breaker position used in the algorithm is considered to be open when the “**CB State Detected**” is “**Breaker Open**”. In all others cases, the breaker position is considered to be closed. Thus, during operation of the circuit breaker, if the condition ‘**52A=52B=0**’ or ‘**52A=52B=1**’ is encountered, the circuit breaker is considered to be closed.

Where single pole tripping is used, then an open breaker condition will only be given if all three phases indicate an open condition. Similarly for a closed breaker condition, indication that all three phases are closed must be given. For single pole tripping applications 52A-a, 52A-b and 52A-c and/or 52B-a, 52B-b and 52B-c inputs should be used. The circuit breaker state monitoring logic diagrams for CB1 & CB2 are shown in AR Figures 1 and 2 (logic diagram supplement).

If inputs relevant to each of the circuit breakers (CB1 and CB2) are available to the relay via the opto isolated inputs, the logic will be able to determine the state of each circuit breaker.

4.4 P446 Circuit Breaker Condition Monitoring

Periodic maintenance of circuit breakers is necessary to ensure that the trip circuit and mechanism operate correctly and also that the interrupting capability has not been compromised due to previous fault interruptions. Generally, such maintenance is based on a fixed time interval or a fixed number of fault current interruptions. These methods of monitoring circuit breaker condition give a rough guide only and can lead to excessive maintenance. The circuit breaker monitoring features of the P446 can help with more efficient maintenance regimes.

4.4.1 P446 Circuit Breaker Condition Monitoring Features

For each trip operation for each circuit breaker the relay records statistics as shown in the following table taken from the relay menu. The menu cells shown are counter values only. The Min./Max. values in this case show the range of the counter values. These cells can not be set.

Menu Text	Default	Setting		Step Size
		Min.	Max.	
CB1 A Operations	0	0	10000	1
Displays the total number of A phase trips issued by the relay for CB1.				
CB1 B Operations	0	0	10000	1
Displays the total number of B phase trips issued by the relay for CB1.				
CB1 C Operations	0	0	10000	1
Displays the total number of C phase trips issued by the relay for CB1.				
CB1 IA Broken	0	0	25000In^	1
Displays the total fault current interrupted by the relay for the A phase for CB1.				
CB1 IB Broken	0	0	25000In^	1
Displays the total fault current interrupted by the relay for the A phase for CB1.				
CB1 IC Broken	0	0	25000In^	1In^
Displays the total fault current interrupted by the relay for the A phase for CB1.				
CB1 Operate Time	0	0	0.5s	0.001
Displays the calculated CB1 operating time.				
Reset CB1 Data	No		Yes, No	
Reset the CB1 condition counters.				
CB2 A Operations	0	0	10000	1
Displays the total number of A phase trips issued by the relay for CB2.				
CB2 B Operations	0	0	10000	1
Displays the total number of B phase trips issued by the relay for CB2.				
CB2 C Operations	0	0	10000	1
Displays the total number of C phase trips issued by the relay for CB2.				
CB2 IA Broken	0	0	25000In^	1
Displays the total fault current interrupted by the relay for the A phase for CB2.				
CB2 IB Broken	0	0	25000In^	1
Displays the total fault current interrupted by the relay for the A phase for CB2.				
CB2 IC Broken	0	0	25000In^	1In^
Displays the total fault current interrupted by the relay for the A phase for CB2.				
CB2 Operate Time	0	0	0.5s	0.001

Menu Text	Default	Setting		Step Size
		Min.	Max.	
Displays the calculated CB2 operating time.				
Reset CB2 Data	No		Yes, No	
Reset the CB2 condition counters.				

Table 26 - Circuit Breaker condition monitoring settings

The counters above may be reset to zero, for example following a maintenance inspection and overhaul. The circuit breaker condition monitoring counters will be updated every time the relay issues a trip command. In cases where the breaker is tripped by an external protection device it is also possible to update the circuit breaker condition monitoring data. This is achieved by allocating one of the P446 opto-isolated inputs (via the programmable scheme logic) to accept a trigger from an external device. The signal that is mapped to the opto is called '**External Trip**'.

Note *When in '**commissioning test mode**' the circuit breaker condition monitoring counters will not be updated.*

The measurement of circuit breaker broken current, operating time and the overall circuit breaker monitoring logic diagram, are shown in Figure 106, Figure 107, Figure 108, Figure 109, Figure 110 and Figure 111.

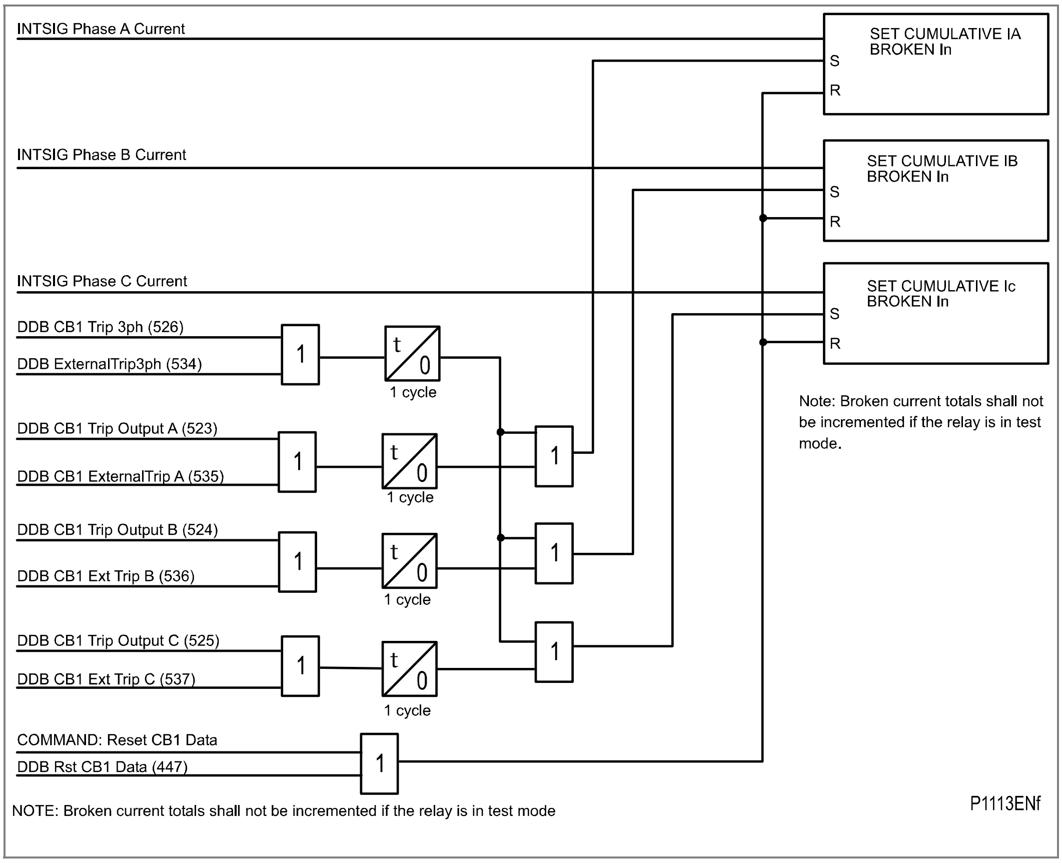

INTSIG Phase A Current
SET CUMULATIVE IA BROKEN In
S
R
INTSIG Phase B Current
SET CUMULATIVE IB BROKEN In
S
R
INTSIG Phase C Current
SET CUMULATIVE Ic BROKEN In
S
R
DDB CB1 Trip 3ph (526)
DDB ExternalTrip3ph (534)
1
t
0
1 cycle
Note: Broken current totals shall not be incremented if the relay is in test mode.
DDB CB1 Trip Output A (523)
DDB CB1 ExternalTrip A (535)
DDB CB1 Trip Output B (524)
DDB CB1 Ext Trip B (536)
DDB CB1 Trip Output C (525)
DDB CB1 Ext Trip C (537)
COMMAND: Reset CB1 Data
DDB Rst CB1 Data (447)
NOTE: Broken current totals shall not be incremented if the relay is in test mode
P1113ENf

Figure 106 - CB1 condition monitoring - broken current

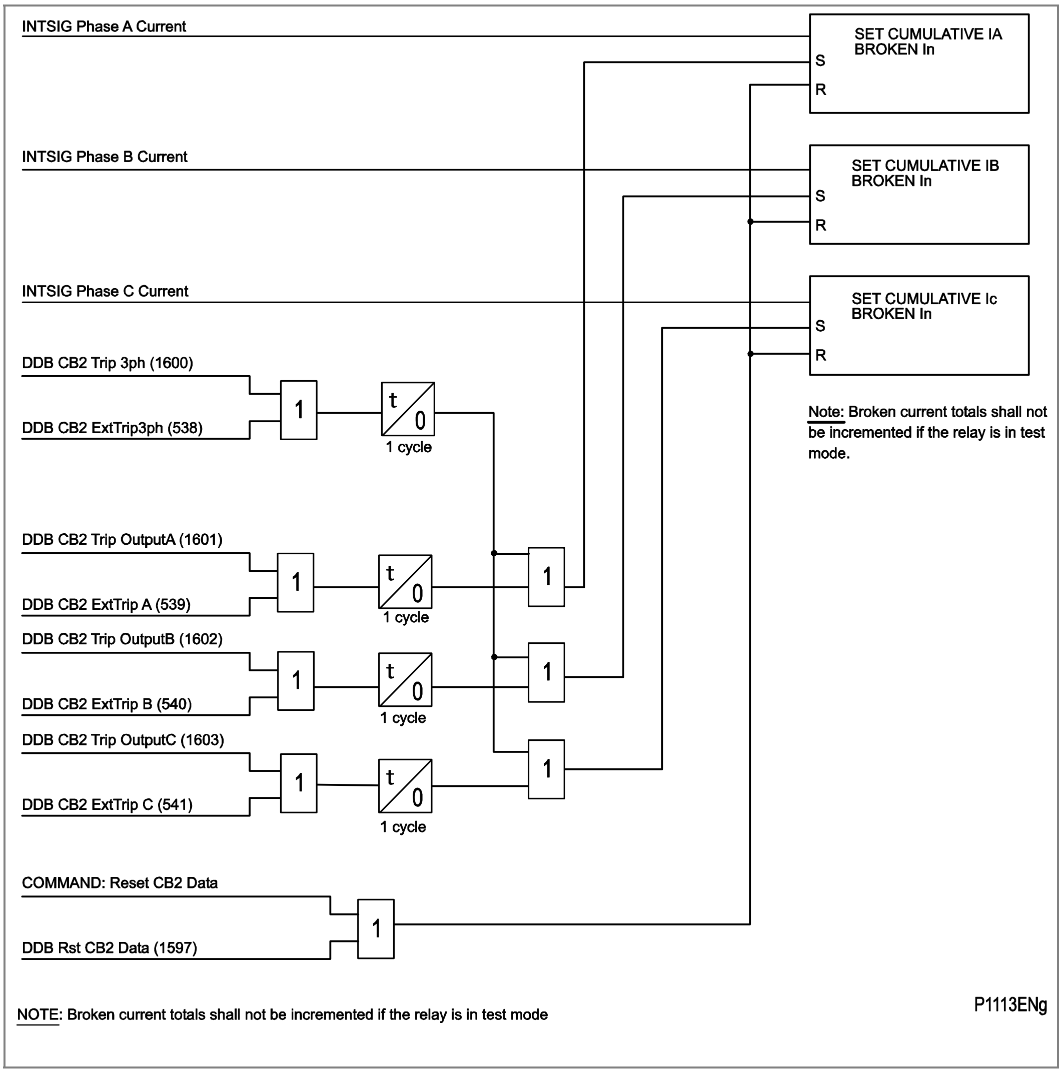

INTSIG Phase A Current
INTSIG Phase B Current
INTSIG Phase C Current
DDB CB2 Trip 3ph (1600)
DDB CB2 ExtTrip3ph (538)
DDB CB2 Trip OutputA (1601)
DDB CB2 ExtTrip A (539)
DDB CB2 Trip OutputB (1602)
DDB CB2 ExtTrip B (540)
DDB CB2 Trip OutputC (1603)
DDB CB2 ExtTrip C (541)
COMMAND: Reset CB2 Data
DDB Rst CB2 Data (1597)
1
t
0
1 cycle
SET CUMULATIVE IA BROKEN In
SET CUMULATIVE IB BROKEN In
SET CUMULATIVE Ic BROKEN In
S
R
Note: Broken current totals shall not be incremented if the relay is in test mode.
NOTE: Broken current totals shall not be incremented if the relay is in test mode
P1113ENg

Figure 107 - CB2 condition monitoring - broken current

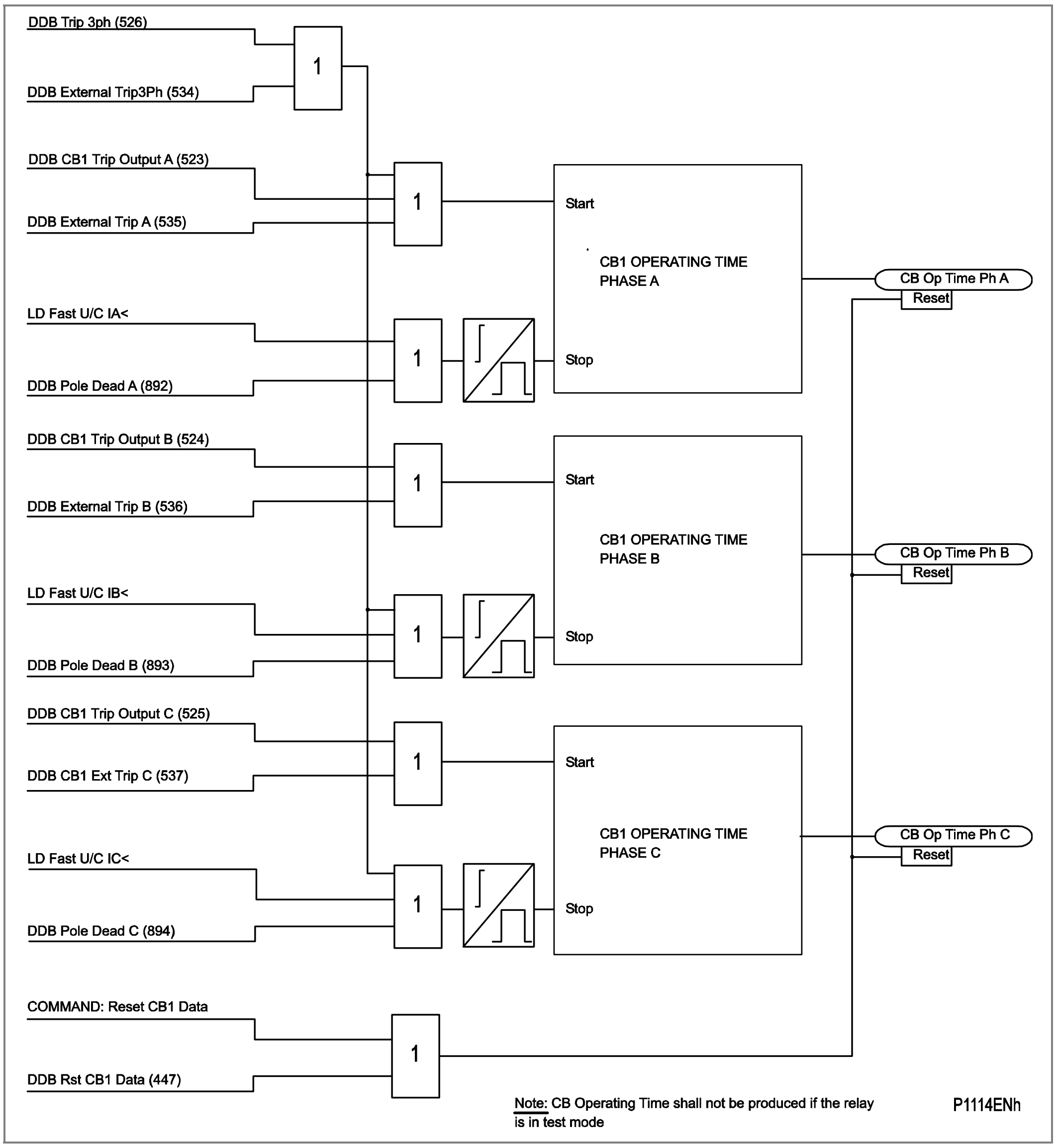

DDB Trip 3ph (526)
DDB External Trip3Ph (534)
DDB CB1 Trip Output A (523)
DDB External Trip A (535)
LD Fast U/C IA<
DDB Pole Dead A (892)
DDB CB1 Trip Output B (524)
DDB External Trip B (536)
LD Fast U/C IB<
DDB Pole Dead B (893)
DDB CB1 Trip Output C (525)
DDB CB1 Ext Trip C (537)
LD Fast U/C IC<
DDB Pole Dead C (894)
COMMAND: Reset CB1 Data
DDB Rst CB1 Data (447)
1
Start
Stop
CB1 OPERATING TIME PHASE A
CB1 OPERATING TIME PHASE B
CB1 OPERATING TIME PHASE C
CB Op Time Ph A
CB Op Time Ph B
CB Op Time Ph C
Reset
Note: CB Operating Time shall not be produced if the relay is in test mode
P1114ENh

Figure 108 - CB1 condition monitoring - operation time

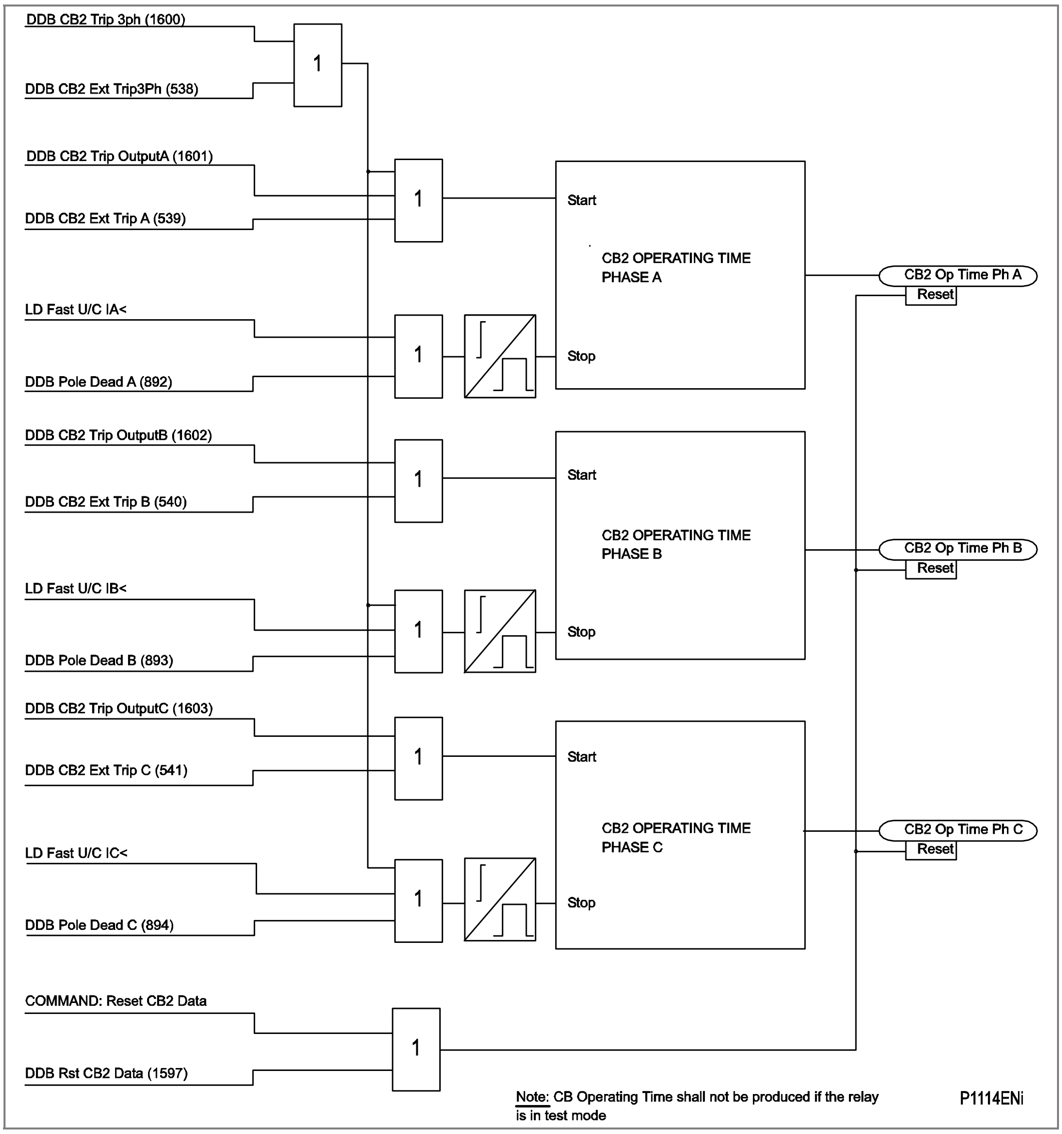

DDB CB2 Trip 3ph (1600)
DDB CB2 Ext Trip3Ph (538)
DDB CB2 Trip OutputA (1601)
DDB CB2 Ext Trip A (539)
LD Fast U/C IA<
DDB Pole Dead A (892)
DDB CB2 Trip OutputB (1602)
DDB CB2 Ext Trip B (540)
LD Fast U/C IB<
DDB Pole Dead B (893)
DDB CB2 Trip OutputC (1603)
DDB CB2 Ext Trip C (541)
LD Fast U/C IC<
DDB Pole Dead C (894)
COMMAND: Reset CB2 Data
DDB Rst CB2 Data (1597)
1
Start
Stop
CB2 OPERATING TIME PHASE A
CB2 OPERATING TIME PHASE B
CB2 OPERATING TIME PHASE C
CB2 Op Time Ph A
CB2 Op Time Ph B
CB2 Op Time Ph C
Reset
Note: CB Operating Time shall not be produced if the relay is in test mode
P1114ENi

Figure 109 - CB2 condition monitoring - operation time

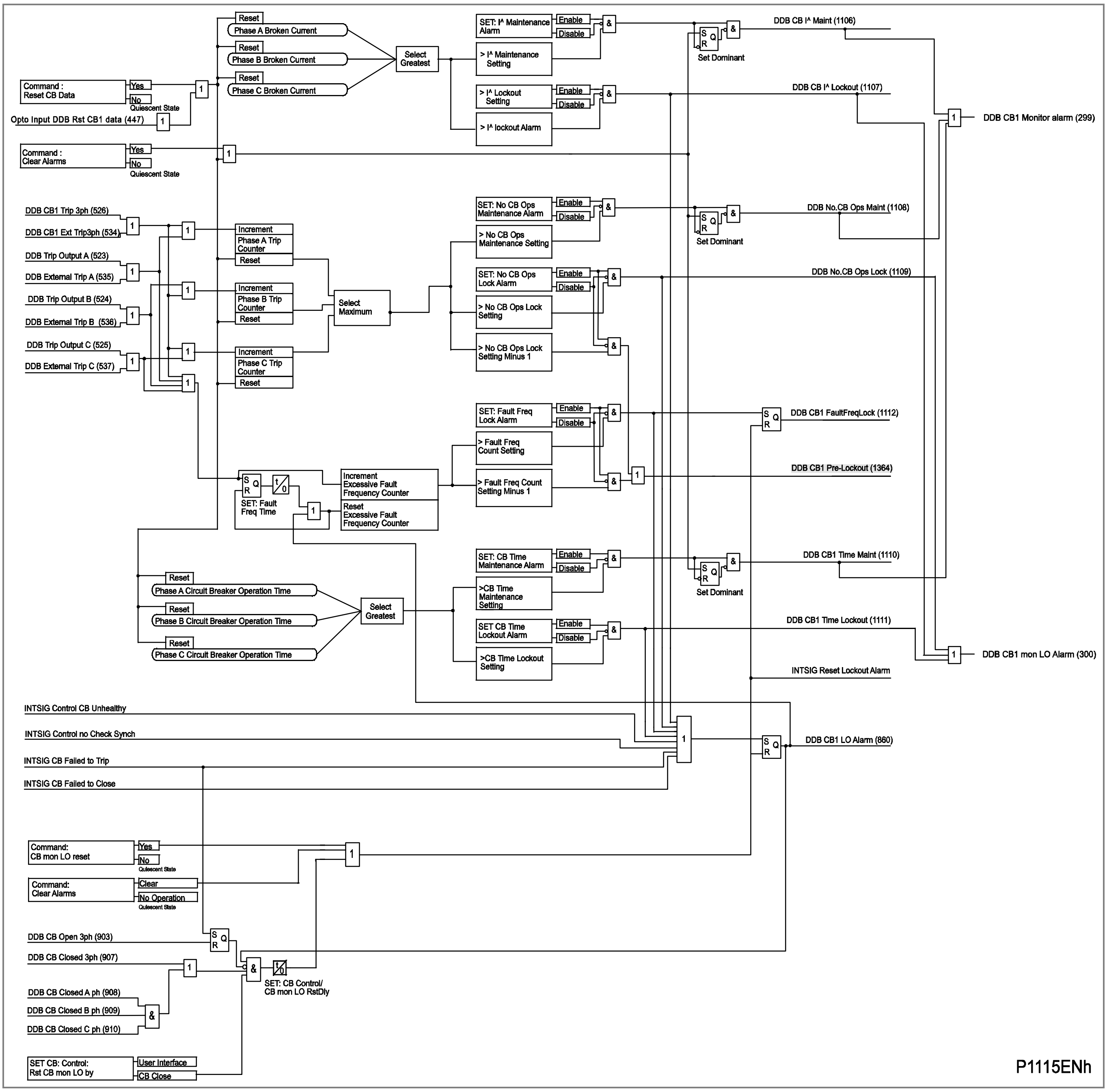

Command : Reset CB Data
Yes
No
Quiescent State
Opto Input DDB Rst CB1 data (447)
Command : Clear Alarms
Yes
No
Quiescent State
Reset
Phase A Broken Current
Reset
Phase B Broken Current
Reset
Phase C Broken Current
Select Greatest
SET: I^ Maintenance Alarm
Enable
Disable
> I^ Maintenance Setting
> I^ Lockout Setting
Enable
Disable
> I^ lockout Alarm
Set Dominant
DDB CB I^ Maint (1106)
DDB CB I^ Lockout (1107)
DDB CB1 Monitor alarm (299)
DDB CB1 Trip 3ph (526)
DDB CB1 Ext Trip3ph (534)
DDB Trip Output A (523)
DDB External Trip A (535)
DDB Trip Output B (524)
DDB External Trip B (536)
DDB Trip Output C (525)
DDB External Trip C (537)
Increment
Phase A Trip Counter
Reset
Increment
Phase B Trip Counter
Reset
Increment
Phase C Trip Counter
Reset
Select Maximum
SET: No CB Ops Maintenance Alarm
Enable
Disable
> No CB Ops Maintenance Setting
SET: No CB Ops Lock Alarm
Enable
Disable
> No CB Ops Lock Setting
> No CB Ops Lock Setting Minus 1
Set Dominant
DDB No.CB Ops Maint (1108)
DDB No.CB Ops Lock (1109)
SET: Fault Freq Lock Alarm
Enable
Disable
> Fault Freq Count Setting
> Fault Freq Count Setting Minus 1
DDB CB1 FaultFreqLock (1112)
DDB CB1 Pre-Lockout (1364)
SET: Fault Freq Time
Increment Excessive Fault Frequency Counter
Reset Excessive Fault Frequency Counter
Reset
Phase A Circuit Breaker Operation Time
Reset
Phase B Circuit Breaker Operation Time
Reset
Phase C Circuit Breaker Operation Time
Select Greatest
SET: CB Time Maintenance Alarm
Enable
Disable
>CB Time Maintenance Setting
SET CB Time Lockout Alarm
Enable
Disable
>CB Time Lockout Setting
Set Dominant
DDB CB1 Time Maint (1110)
DDB CB1 Time Lockout (1111)
DDB CB1 mon LO Alarm (300)
INTSIG Reset Lockout Alarm
INTSIG Control CB Unhealthy
INTSIG Control no Check Synch
INTSIG CB Failed to Trip
INTSIG CB Failed to Close
DDB CB1 LO Alarm (860)
Command: CB mon LO reset
Yes
No
Quiescent State
Command: Clear Alarms
Clear
No Operation
Quiescent State
DDB CB Open 3ph (903)
DDB CB Closed 3ph (907)
DDB CB Closed A ph (908)
DDB CB Closed B ph (909)
DDB CB Closed C ph (910)
SET: CB Control/ CB mon LO RstDly
SET CB: Control: Rst CB mon LO by
User Interface
CB Close
P1115ENh

Figure 110 - Circuit breaker 1 - monitoring

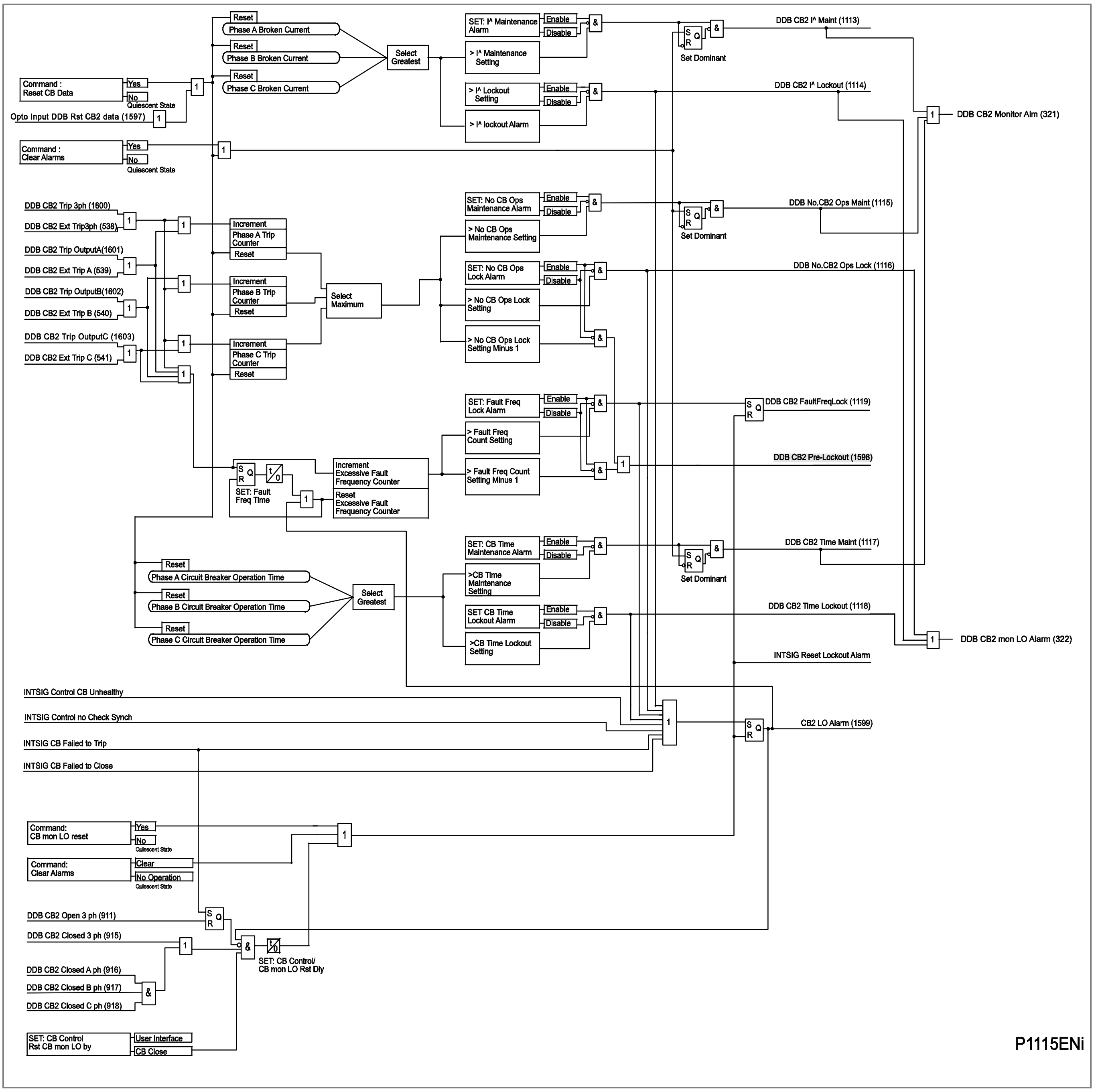

Reset
Phase A Broken Current
Reset
Phase B Broken Current
Reset
Phase C Broken Current
Select Greatest
Command : Reset CB Data
Yes
No
Quiescent State
Opto Input DDB Rst CB2 data (1597)
Command : Clear Alarms
Yes
No
Quiescent State
SET: I^ Maintenance Alarm
Enable
Disable
> I^ Maintenance Setting
> I^ Lockout Setting
Enable
Disable
> I^ lockout Alarm
&
S Q R
Set Dominant
DDB CB2 I^ Maint (1113)
DDB CB2 I^ Lockout (1114)
DDB CB2 Monitor Alm (321)
DDB CB2 Trip 3ph (1600)
DDB CB2 Ext Trip3ph (538)
DDB CB2 Trip OutputA(1601)
DDB CB2 Ext Trip A (539)
DDB CB2 Trip OutputB(1602)
DDB CB2 Ext Trip B (540)
DDB CB2 Trip OutputC (1603)
DDB CB2 Ext Trip C (541)
Increment
Phase A Trip Counter
Reset
Increment
Phase B Trip Counter
Reset
Increment
Phase C Trip Counter
Reset
Select Maximum
SET: No CB Ops Maintenance Alarm
Enable
Disable
> No CB Ops Maintenance Setting
SET: No CB Ops Lock Alarm
Enable
Disable
> No CB Ops Lock Setting
> No CB Ops Lock Setting Minus 1
DDB No.CB2 Ops Maint (1115)
DDB No.CB2 Ops Lock (1116)
SET: Fault Freq Lock Alarm
Enable
Disable
> Fault Freq Count Setting
> Fault Freq Count Setting Minus 1
DDB CB2 FaultFreqLock (1119)
DDB CB2 Pre-Lockout (1598)
SET: Fault Freq Time
Increment Excessive Fault Frequency Counter
Reset Excessive Fault Frequency Counter
t 0
SET: CB Time Maintenance Alarm
Enable
Disable
>CB Time Maintenance Setting
SET CB Time Lockout Alarm
Enable
Disable
>CB Time Lockout Setting
DDB CB2 Time Maint (1117)
DDB CB2 Time Lockout (1118)
DDB CB2 mon LO Alarm (322)
INTSIG Reset Lockout Alarm
Reset
Phase A Circuit Breaker Operation Time
Reset
Phase B Circuit Breaker Operation Time
Reset
Phase C Circuit Breaker Operation Time
Select Greatest
INTSIG Control CB Unhealthy
INTSIG Control no Check Synch
INTSIG CB Failed to Trip
INTSIG CB Failed to Close
CB2 LO Alarm (1599)
Command: CB mon LO reset
Yes
No
Quiescent State
Command: Clear Alarms
Clear
No Operation
Quiescent State
DDB CB2 Open 3 ph (911)
DDB CB2 Closed 3 ph (915)
DDB CB2 Closed A ph (916)
DDB CB2 Closed B ph (917)
DDB CB2 Closed C ph (918)
SET: CB Control/ CB mon LO Rst Dly
SET: CB Control Rst CB mon LO by
User Interface
CB Close
P1115ENi

Figure 111 - Circuit breaker 2 - monitoring

4.5 P446 Circuit Breaker Control

This functionality shows how a circuit breaker close signal from the auto-reclose logic “**AutoClose CBx**” (x = 1 or 2) is applied alongside operator controlled circuit breaker close and trip control.

See AR Figures 43 & 44 (logic diagram supplement) for CB1 & CB2 circuit breaker control respectively.

The P446 includes the following options for the control of each of the two circuit breakers:

- Local tripping and closing, via the relay menu or *Hotkeys*
- Local tripping and closing, via relay opto-isolated inputs
- Remote tripping and closing, using the relay communications
- Auto-reclosing via “**Auto Close CB1**” or “**Auto Close CB2**” signal from CB1 & CB2 Auto Close logic

It is recommended that separate relay output contacts are allocated for remote circuit breaker control and protection tripping. This enables the control outputs to be selected via a local/remote selector switch as shown in Figure 113. Where this feature is not required the same output contact(s) can be used for both protection and remote tripping.

In the case of the P446, the two circuit breakers may be selectively controlled both locally and remotely if relay contacts are assigned to allow a separate control trip contact and a separate control close for each circuit breaker i.e. four output relay contacts.

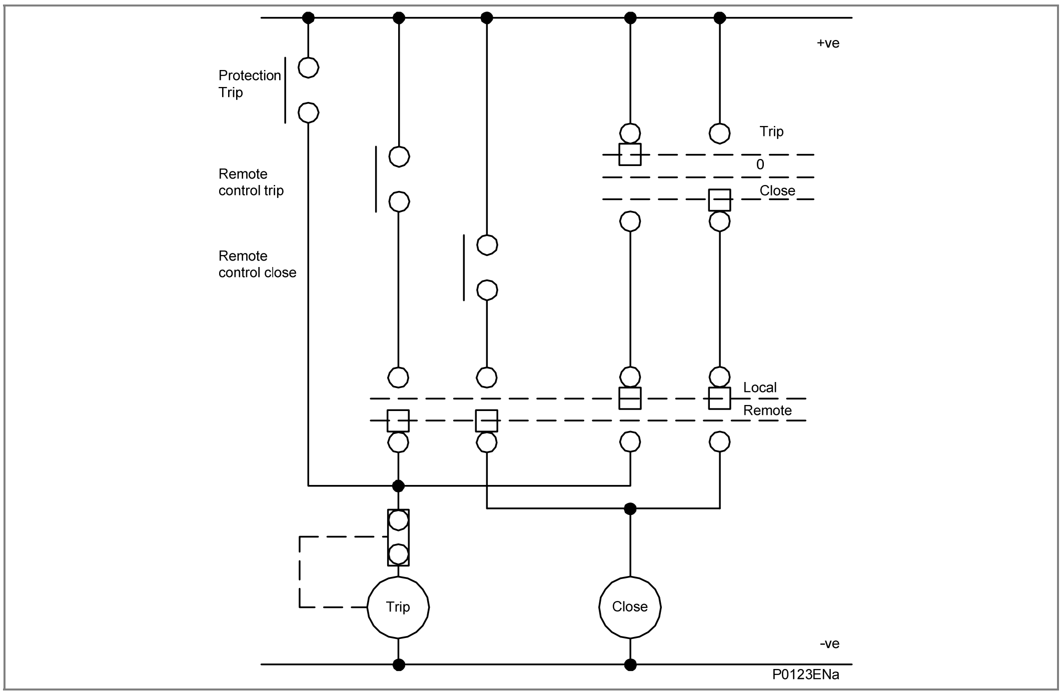


Figure 112 - Remote control of circuit breaker

A manual trip will be permitted provided that the circuit breaker is initially closed. Likewise, a close command can only be issued if the circuit breaker is initially open. To confirm these states it will be necessary to use the circuit breaker 52A and/or 52B contacts (the different selection options are given from the “**CBx Status Input**” cell above). If no circuit breaker auxiliary contacts are available then this cell should be set to “**None**”. Under these circumstances no circuit breaker control (manual or auto) will be possible.

A circuit breaker close command ("**Close CB1**" for CB1 or "**Close CB2**" for CB2) will initiate closing of the circuit breaker. The output contact, however, can be set to operate following a user defined time delay ('**Man Close Delay**'). This is designed to give personnel time to retreat from the circuit breaker following the close command. This time delay applies to all manual circuit breaker close commands.

The control close cycle can be cancelled at any time before the output contact operates by any appropriate trip signal, or by activating DDB (443): "**Rst CB1 CloseDly**" for CB1 or by DDB (1419): "**Rst CB2 CloseDly**" for CB2.

An "**Auto Close CB1**" or "**Auto Close CB2**" signal from the "**Auto close**" logic bypasses the "**Man Close Delay**" time, and the "**CB1 Close**" or "**CB2 Close**" outputs operate immediately to close the circuit breaker.

The length of the trip or close control pulse is set via the "**Trip Pulse Time**" and "**Close Pulse Time**" settings respectively. These should be set long enough to ensure the breaker has completed its open or close cycle before the pulse has elapsed.

Note *The manual trip and close commands are found in the SYSTEM DATA column and the hotkey menu.*

If an attempt to close the circuit breaker is being made and a protection trip signal is generated, the protection trip command overrides the close command.

If the system check synchronism function is set, this can be enabled to supervise manual circuit breaker close commands. A circuit breaker close output will only be issued if the check synchronism criteria are satisfied. Different system check criteria can be selected for control closing CB1 and CB2. A user settable time delay ("**Check Sync Time**") is included to supervise manual closure with check synchronizing criteria. If the check synchronism criteria are not satisfied in this time period following a close command the relay will lockout and alarm.

Before manual re-closure, in addition to a synchronism check, there is also a circuit breaker healthy check, "**CB Healthy**", which requires the circuit breaker to be capable of closing safely (for example, having its closing spring fully charged and/or gas pressure sufficient for a close and immediate fault trip), as indicated by DDB input "**CBx Healthy**" (x = 1 or 2). A user settable time delay "**CB Healthy Time**" is included for manual closure with this check. If the circuit breaker does not indicate a healthy condition in this time period following a close command (DDB input is still low when the set time has elapsed) then the relay will lockout the relevant circuit breaker and set an alarm.

If auto-reclose is used it may be desirable to block its operation when performing a manual close. In general, the majority of faults following a manual closure will be permanent faults and it will be undesirable to allow auto-reclose.

To ensure that auto-reclosing is not initiated for a manual circuit breaker closure on to a pre-existing fault (switch on to fault), the AUTO-RECLOSE menu setting "**CB IS Time**" (circuit breaker in service time) should be set for the desired time window. This setting ensures that auto-reclose initiation is inhibited for a period equal to setting "**CB IS Time**" following a manual circuit breaker closure. If a protection operation occurs during the inhibit period, auto-reclosing is not initiated.

Following manual circuit breaker closure, if either a single phase or a three phase fault occurs during the inhibit period, the circuit breaker is tripped three phase, but auto-reclose is not locked out for this condition.

If the circuit breaker fails to respond to the control command (indicated by no change in the state of CBx Status inputs) a '**CBx Trip Fail**' or '**CBx Close Fail**' alarm (x = 1 or 2) will be generated after the relevant '**Trip pulse Time**' or '**Close Pulse Time**' has expired. These alarms can be viewed on the relay LCD display, remotely via the relay communications, or can be assigned to operate output contacts for annunciation using the relays programmable scheme logic (PSL).

It should be noted that the “**CB Healthy Time**” timer and “**Check Sync Time**” timer described in this menu section are applicable to manual circuit breaker operations only. These settings are duplicated in the auto-reclose menu for auto-reclose applications.

For the description of settings and commands related to the various methods for resetting circuit breaker lockouts, refer to section 4.6.6.18 - Reset CB Lockout.

4.5.1 Circuit Breaker Control using Hotkeys

The hotkeys allow direct access to the manual trip and close commands without the need to use the SYSTEM DATA column of the menu. Red or green color coding can be applied when used in circuit breaker control applications.

IF <<TRIP>> or <<CLOSE>> is selected the user is prompted to confirm the execution of the relevant command. If a “**trip**” is executed, a screen displaying the circuit breaker status will be displayed once the command has been completed. If a “**close**” is executed a screen with a timing bar will appear while the command is being executed. This screen has the option to cancel or restart the close procedure. The timer used is taken from the manual close delay timer setting in the “**CB Control**” menu. If the command has been executed, a screen confirming the present status of the circuit breaker will be displayed. The user is then prompted to select the next appropriate command or to exit - this will return to the default relay screen.

If no keys are pressed for a period of 25 seconds whilst the P446 is waiting for the command confirmation, the P446 will revert to showing the circuit breaker status. If no key presses are made for a period of 25 seconds whilst the P446 is displaying the circuit breaker status screen, the P446 will revert to the default relay screen. Figure 113 shows the hotkey menu associated with circuit breaker control functionality.

To avoid accidental operation of the trip and close functionality, the hotkey circuit breaker control commands are disabled for 10 seconds after exiting the hotkey menu.

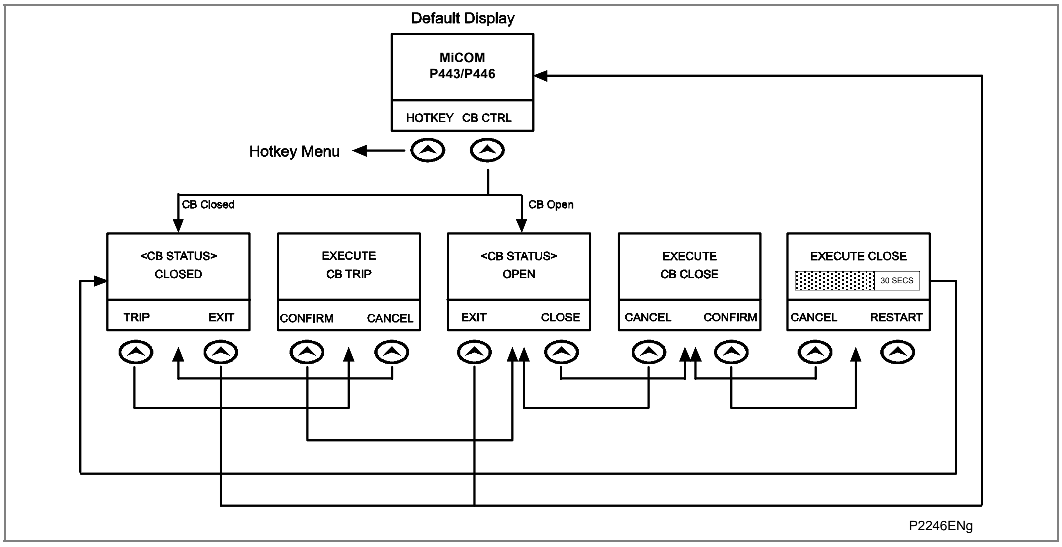


Figure 113 - Circuit breaker control hotkey menu

4.5.2 Circuit Breaker Control using Function Keys

The function keys allow direct control of the circuit breaker if programmed to do this in the PSL. Local tripping and closing must be set in the “**CB Control**” menu “**CB control by**” cell to one of the via “**opto**” settings to enable this functionality. All circuit breaker manual control settings and conditions will apply for manual tripping and closing via function keys.

The following default logic can be programmed to activate this feature for CB1:

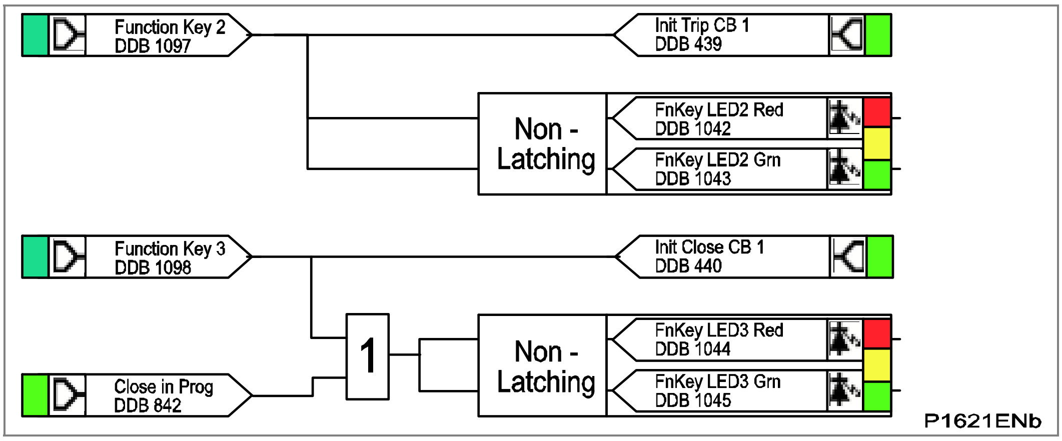

Function Key 2
DDB 1097
Init Trip CB 1
DDB 439
Non - Latching
FnKey LED2 Red
DDB 1042
FnKey LED2 Grn
DDB 1043
Function Key 3
DDB 1098
Init Close CB 1
DDB 440
1
Close in Prog
DDB 842
Non - Latching
FnKey LED3 Red
DDB 1044
FnKey LED3 Grn
DDB 1045
P1621ENb

Figure 114 - Circuit breaker control via function keys default PSL

Function key 2 and function key 3 are both enabled and set to '**Normal**' Mode and the associated DDB signals (1097) and (1098) will be active high '**1**' on a key press.

The following DDB signals must be mapped to the relevant function key:

Init Trip CB1	(DDB 439) - Initiate manual circuit breaker CB1 trip
Init Close CB1	(DDB 440) - Initiate manual circuit breaker CB1 close

The programmable function key LED's have been mapped such that the LED's will indicate yellow whilst the keys are activated.

The diagram shows the control of CB1 only for simplicity. CB2 can be controlled in a similar way and the relevant DDB signals are (441) Init Trip CB2, and (442) Init Close CB2.

4.6 P446 Single and Three Phase Auto-Reclosing

The auto-reclose scheme in the P446 provides single phase or three phase auto-reclosing of a feeder terminal switched by one or two circuit breakers.

With the P446, the user can select to initiate auto-reclosure following any Zone 1, or distance-aided scheme trips which occur. In addition, the user can selectively decide to auto-reclose for trips from time-delayed distance zones, overcurrent and earth (ground) elements, and DEF aided schemes.

In a two circuit breaker scheme, the circuit breakers are normally arranged to re-close sequentially with one designated leader circuit breaker re-closing after a set dead time followed, if the leader circuit breaker remains closed, by the second circuit breaker after a further delay, the follower time. In the operational description, the two circuit breakers are designated as CB1 and CB2. The scheme can be configured by menu settings, by control commands, or by opto inputs to operate in any of the following modes for the first shot (first auto-reclose attempt):

Leader CB	Leader AR mode	Follower CB	Follower AR Mode
CB1	1Ph	CB2	1Ph or 3Ph
CB1	3Ph	CB2	3Ph
CB1	1/3Ph	CB2	1/3Ph or 3Ph
CB1	1Ph, 3P or 1/3Ph	No follower AR	No follower AR
CB2	1Ph	CB1	1Ph or 3Ph
CB2	3Ph	CB1	3Ph
CB2	1/3Ph	CB1	1/3Ph or 3Ph
CB2	1Ph, 3P or 1/3Ph	No follower AR	No follower AR

Table 27 - Leader and Follower CB and AR modes

If “**1Ph**” or “**1/3Ph**” follower auto-reclose mode is selected, the follower can perform single phase auto-reclose only if the leader circuit breaker has performed single phase auto-reclose. If the leader has tripped and re-closed three phase, the follower is also forced to trip three phase, and will then re-close three phase provided three phase auto-reclose is permitted for the follower circuit breaker. If the follower circuit breaker trips three phase, and three phase auto-reclose is not permitted for the follower, then the follower circuit breaker will lock out without re-closing.

Single phase re-closing is permitted only for the first shot of an auto-reclose cycle. If two or more shots are enabled, then in a multi-shot auto-reclose cycle the second and subsequent trips and re-closures will be three phase.

The scheme can be configured to control a single circuit breaker installation. If the menu setting “**Num CBs**” is set to “**CB1 Only**”, all menu settings and indications relating to CB2 are redundant and hidden, and the scheme controls only CB1. If the menu setting “**Num CBs**” is set to “**CB2 Only**”, all menu settings and indications relating to CB1 are redundant and hidden, and the scheme controls only CB2. In these single circuit-breaker configurations, the selected circuit-breaker auto-reclose can be selected to “**1Ph**”, “**3Ph**” or “**1/3Ph AR mode**” indicating single phase, three phase, or single/three phase operation.

4.6.1 Time Delayed and High Speed Auto-Reclosing

The auto-reclose function offers multi-shot auto-reclose control, selectable to perform up to a four shot cycle. Dead times (Note 1) for all shots (Note 2) are independently adjustable. Should a circuit breaker close successfully at the end of the dead time, a “**Reclaim Time**” starts. If the circuit breaker does not trip again, the auto-reclose function resets at the end of the reclaim time. If the protection trips again during the reclaim time the relay advances to the next shot in the programmed cycle, or, if all programmed re-close attempts have been made, the auto-reclose goes to lockout.

Note 1	*“**Dead Time**” denotes the open (dead) interval delay of the CB*
Note 2	*A “**Shot**” is a reclosure attempt*

4.6.2 P446 Auto-Reclose Logic Inputs

The auto-reclose function uses inputs in the logic, which can be assigned and activated from any of the opto-isolated inputs on the relay via the programmable scheme logic (PSL). Contacts from external equipment may be used to influence the auto-recloser via the optos, noting that the circuit breaker status (open/closed) must also be available via auxiliary contact inputs to the relay.

These logic inputs can also be assigned and activated from other sources. The function of these inputs is described below, identified by their DDB signal text. The inputs can be selected to accept either a normally open or a normally closed contact, programmable via the PSL editor.

4.6.2.1 CB Healthy

The majority of circuit breakers are only capable of providing one trip-close-trip cycle. Following this, it is necessary to re-establish sufficient energy in the circuit breaker (spring charged, gas pressure healthy, etc.) before the circuit breaker can be re-closed.

The DDB “**CB Healthy**" input is used to ensure that there is sufficient energy available to close and trip the circuit breaker before initiating a “**CB Close**” command. If on completion of the dead time, the DDB “**CB Healthy**" input is low, and remains low for a period given by the "**CB Healthy Time**" timer, lockout will result and the circuit breaker will remain open

DDBs (436 & 437) are used for “**CB1 Healthy**” & “**CB2 Healthy**” respectively to enable “**CB1 Close**” and “**CB2 Close**” by auto-reclose. The “**CB Healthy Time**” setting is common to both CB1 and CB2.

This check can be disabled by not allocating an opto input for DDB “**CB Healthy**". The signal defaults to high if no logic is mapped to DDB within the PSL in the relay

4.6.2.2 P446 Inhibit Auto-Reclose

An external input can be used to inhibit auto-reclose. The signal is available for mapping via the PSL from an opto input or a communications input.

The signal is “**Inhibit AR**”, DDB (1420). This single signal applies to both CB1 and CB2.

Energizing the input will cause any auto-switching to be inhibited. Any auto-reclose in progress will be reset and inhibited, but not locked out. It is provided to ensure that auto-switching does not interfere with any manual switching. A typical application would be on a mesh-corner scheme where manual switching is being performed on the mesh, for which any auto-reclose would cause interference.

If a single phase auto-reclose cycle is in progress and a single pole of the circuit breaker is tripped when this signal is raised, a ‘**force three phase trip output**’, (“**AR Force 3 pole**”, DDB (858)) will be set. This is to force the circuit breaker to trip the other phases thereby ensuring that all poles will be in the same state (and avoiding a pole stuck condition) when subsequent closing of the circuit breaker is attempted.

4.6.2.3 P446 Block Auto-Reclose

External inputs can be used to block auto-reclose. Two signals (one for each circuit breaker controlled) are available for mapping via the PSL from opto inputs or communications inputs.

The two signals are:

- “**Block CB1 AR**” DDB (448)
- “**Block CB2 AR**“ DDB (1421)

The “**Block CB AR**” input, if asserted, will block the operation of the auto-reclose cycle and, if auto-reclose is in progress, it will force the circuit breaker to lockout.

Typically it is used where, dependent upon the type of protection operation, auto-reclose may, or may not, be required. An example is on a transformer feeder, where auto-reclosing may be initiated from the feeder protection but blocked from the transformer protection.

“**Block CB AR**” can also be used in cases where the auto-reclose cycle is likely to fail for conditions associated with the protected circuit. The input can be used for example if, anywhere during the dead time, a circuit breaker indicates that it is not capable of switching (low gas pressure or loss of vacuum alarm occurs).

4.6.2.4 P446 Reset Lockout

The “**Reset Lockout**” input can be used to reset the auto-reclose function following lockout and reset any auto-reclose alarms, provided that the signals which initiated the lockout have been removed.

The following DDB signals are available for mapping in PSL from opto inputs or communications inputs:

- DDB (446) “**Rst CB1 Lockout**”: Reset Lockout Opto Input to reset CB1 Lockout state
- DDB (1422) “**Rst CB2 Lockout**”: Reset Lockout Opto Input to reset CB2 Lockout state

4.6.2.5 P446 Pole Discrepancy

Circuit breakers with independent mechanisms for each pole normally incorporate a ‘**phases not together**’ or ‘**pole discrepancy**’ protection device which automatically trips all three phases if they are not all in the same position i.e. all open or all closed.

During single pole auto-reclosing a pole discrepancy condition is deliberately introduced and the pole discrepancy device must not operate for this condition. This may be achieved by using a delayed action pole discrepancy device with a delay longer than the single pole auto-reclose dead time, “**SP AR Dead Time**”.

Alternatively, a signal can be given from the relay during the single pole auto-reclose dead time, “**AR 1 Pole In Progress**”, to inhibit the external pole discrepancy device.

In the relay, the “**Pole Discrepancy**” input is activated by a signal from an external device indicating that all three poles of the CB are not in the same position. The “**Pole Discrepancy**” inputs, DDB (451) & DDB (1606) forces a 3 pole trip on CB1 & CB2 respectively through PSL mapping.

The logic diagram for the pole discrepancy is shown in Figure AR 171 (logic diagram supplement).

4.6.2.6 P446 External Trip

The "**External Trip 3Ph**" input and the "**External Trip A**", "**External Trip B**" and "**External Trip C**" inputs can be used to initiate three or single phase auto-reclose.

Note *These signals are not used to trip the circuit breaker but do initiate auto-reclose. To trip the circuit breaker directly they could be assigned to the trip contacts of the relay in the PSL.*

The following DDB signals are available for mapping in PSL from opto inputs to initiate auto-reclosing.

- DDB (535): "CB1 Ext Trip A"
- DDB (536): "CB1 Ext Trip B"
- DDB (537): "CB1 Ext Trip C"
- DDB (534): "CB1 Ext Trip 3Ph"
- DDB (539): "CB2 Ext Trip A"
- DDB (540): "CB2 Ext Trip B"
- DDB (541): "CB2 Ext Trip C"
- DDB (538): "CB2 Ext Trip 3Ph"

4.6.3 P446 Internal Signals

4.6.3.1 P446 Trip Initiate Signals

The "**Trip Inputs A**", "**Trip Inputs B**" and "**Trip Inputs C**" signals are used to initiate single or three phase auto-reclose.

Note *For single phase auto-reclose these signals must be mapped in the PSL as shown in the default.*

4.6.3.2 P446 Circuit Breaker Status

The "**CB Open 3 ph**", "**CB Open A ph**", "**CB Open B ph**" and "**CB Open C ph**", signals are used to indicate if a circuit breaker is open three or single phase. These are driven from the internal pole dead logic and the circuit breaker auxiliary inputs.

The "**CB Closed 3 ph**", "**CB Closed A ph**", "**CB Closed B ph**" and "**CB Closed C ph**", signals are used to indicate if a circuit breaker is closed three or single phase. These are driven from the internal pole dead logic and the circuit breaker auxiliary inputs.

4.6.3.3 P446 Check Synch OK and System Check OK

Internal signals generated from the internal system check function and external system check equipment are used by the internal auto-reclose logic to permit auto-reclosure.

DDB (883) "**CB1 CS1 OK**" & DDB (884) "**CB1 CS2 OK**" are output from CB1 Check Sync logic and indicate conditions for CB1 sync check stage1 & 2 are satisfied.

DDB (1577) "**CB2 CS1 OK**" & DDB (1463) "**CB2 CS2 OK**" are output from CB2 Check Sync logic and indicate conditions for CB2 sync check stage1 & 2 are satisfied.

4.6.4 P446 Auto-Reclose Logic Outputs

The “**CB1 AR 1p InProg**” (DDB 845) and the “**CB2 AR 1p InProg**” (DDB 855) output signals indicate that single phase auto-reclose is in progress. The outputs remain high from protection initiation until lockout, or successful re-closure of the circuit breaker which is indicated by the circuit breaker successful auto-reclose signals, “**CB1 Succ 1P AR**” (DDB 1571) and “**CB2 Succ 1P AR**” (DDB 1451) generated by the logic for CB1 and CB2 respectively.

The “**CB1 AR 3p InProg**” (DDB 844) and “**CB2 AR 3p InProg**” (DDB 1411) output signals indicate that three phase auto-reclose is in progress. The outputs remain high from protection initiation until lockout, or successful re-closure of the circuit breaker which is indicated by the circuit breaker successful auto-reclose signals, “**CB1 Succ 3P AR**” (DDB 852) and “**CB2 Succ 3P AR**” (DDB 1452) for generated by the logic for CB1 and CB2 respectively.

Any auto-reclose lockout condition will reset all auto-reclose in progress signals associated with that circuit breaker (e.g. “**ARIP**”).

4.6.5 P446 Auto-Reclose Logic Operating Sequence

For simplicity, the auto-reclose operating sequence is described for the case of a single circuit breaker, CB1 only.

The same operating sequence would apply if CB2 only was enabled.

In a dual breaker application, the same operating sequence would apply to the leader circuit breaker and, provided the leader circuit breaker remained closed after the set dead time, the follower circuit breaker would re-close after a further delay (the follower time).

Note	*In a dual circuit breaker application, the settings describing single and three phase auto-reclose “**AR 1P**” “**AR 3P**” and “**AR 1/3P**” below would change in the dual breaker case to reflect the mode of the leader circuit breaker “**L1P**”, “**L3P**”, “**L1/3P**”.*

Following this introduction to the logic sequence, is a comprehensive description of the auto-reclose and circuit breaker operation.

An auto-reclose cycle can be internally initiated by operation of a protection element, provided the circuit breaker is closed until the instant of protection operation.

The operation of the auto-reclose sequence is controlled by the “**Dead Timers**”. The user can, via settings, determine what conditions will be used to initiate the dead timers as described in section 4.6.6.9. In general, however, and for the purposes of this description, the dead timers can be considered to start upon initiation of the auto-reclose cycle by the protection.

If only single phase auto-reclose “**AR 1P**” is enabled then the logic allows only a single shot auto-reclose. For a single phase fault, the single phase dead timer "**SP AR Dead Time**" starts, and the single phase auto-reclose in progress signal “**CB1 AR 1p InProg**” (DDB 845) is asserted. For a multi-phase fault the logic triggers a three phase trip and goes to lockout.

If only three phase auto-reclose “**AR 3P**” is enabled then, for any fault, the three phase dead timers: "**3P AR DT Shot 1**”, “**3P AR DT Shot 2**”, “**3P AR DT Shot 3**”, “**3P AR DT Shot 4**", (Dead Time 1, 2, 3, 4) are started and the three phase auto-reclose in progress signal “**CB1 AR 3p InProg**” (DDB 844) is asserted. The logic forces a three phase trip by setting “**AR Force CB1 3P**” (DDB 858) for any single phase fault if only three phase auto-reclose “**AR 3P**” is enabled.

If single and three phase auto-reclose “**AR1/3P**” are enabled then, if the first fault is a single phase fault the single phase dead time "**SP AR Dead Time**" is started and the single phase auto-reclose in progress signal “**CB1 AR 1p InProg**” (DDB 845) is asserted.

If the first fault is a multi-phase fault the three phase dead timer "**3P AR DT Shot 1**" is started and the three phase auto-reclose in progress signal “**CB1 AR 3p InProg**” (DDB 844) is asserted. If the relay has been set to allow more than one reclose (“**AR Shots >1**”) then any subsequent faults will be converted to three phase trips by setting the signal “**AR Force CB1 3P**” (DDB 858). The three phase dead times "**3P AR DT Shot 2**”, “**3P AR DT Shot 3**” and “**3P AR DT Shot 4**" (Dead Times 2, 3, 4) will be started for the 2nd, 3rd and 4th trips (shots) respectively. The three phase auto-reclose in progress signal “**CB1 AR 3p InProg**” (DDB 844) will be asserted. If a single phase fault evolves to a multi-phase fault during the single phase dead time (“**SP AR Dead Time**”) then single phase auto-reclose is stopped. The single phase auto-reclose in progress signal “**CB1 AR 1p InProg**” (DDB 845) is reset, the three phase auto-reclose in progress signal “**CB1 AR 3p InProg**” (DDB 844) is set, and the three phase dead timer “**3P AR DT Shot 1**” is started.

At the end of the relevant dead time, provided system conditions are suitable, a circuit breaker close signal is given. The system conditions to be met for closing are that the system voltages are in synchronism or that the dead line/live bus or live line/dead bus conditions exist, indicated by the internal system check synchronizing element, and that the circuit breaker closing spring, or other energy source, is fully charged as indicated by the “**CB Healthy**” input. The circuit breaker close signal is cut-off when the circuit breaker closes. For single phase auto-reclose no voltage or synchronism check is required as synchronizing power is flowing in the two healthy phases. For three phase auto-reclosing, for the first shot only, auto-reclose can be performed without checking that the voltages are in synchronism by means of a setting. This setting, “**CBxL SC Shot 1**”, can be set to “**Enabled**” to perform synch-checks on shot 1 for CB1 or CB2, or “**Disabled**” to not perform the checks.

When the circuit breaker has closed, the “**Set CB1 Close**” (DDB 1565) signal from the “**CB auto-close logic**” goes high and the reclaim time (“**Reclaim Time**”) starts. If the circuit breaker has remained closed and not tripped again when the reclaim timer expires, the auto-reclose cycle is complete, and signal “**CB1 Succ 1P AR**” (DDB1571) or “**CB1 Succ 3P AR**” (DDB 852) is generated to indicate the successful re-closure. These signals also increment the relevant circuit breaker successful auto-reclose shot counters “**CB1 SUCC SPAR**”, “**CB1 SUCC 3PAR Shot1**”, “**CB1 SUCC 3PAR Shot2**”, “**CB1 SUCC 3PAR Shot3**” and “**CB1 SUCC 3PAR Shot4**”, as well as resetting the circuit breaker auto-reclose in progress “**CB1 ARIP**” signal.

If the protection operates and circuit breaker trips during the reclaim time the relay either advances to the next shot in the programmed auto-reclose cycle, or, if all programmed re-close attempts have been made, the circuit breaker goes to lockout. Every time the relay trips the sequence counter is incremented by 1 and the reclaim time starts again after each shot, following the “**Set CB1 Close**” signal going high again.

For multi-phase faults the auto-reclose logic can be set to allow auto-reclose block for 2 and 3 phase faults or to allow auto-reclose block for 3 phase faults only using the setting “**Multi Phase AR**” in the AUTORECLOSE settings, where the options are “**Allow Autoclose**”, “**BAR 2 & 3 ph**” and “**BAR 3 Phase**”.

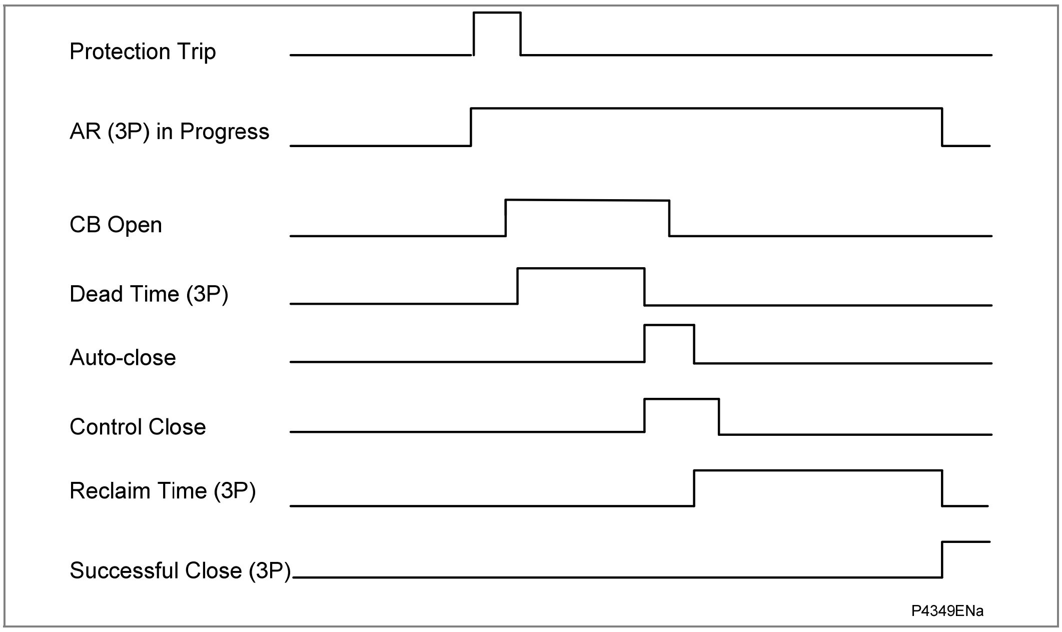

Protection Trip
AR (3P) in Progress
CB Open
Dead Time (3P)
Auto-close
Control Close
Reclaim Time (3P)
Successful Close (3P)
P4349ENa

Figure 115 - Auto-reclose timing diagram - single fault

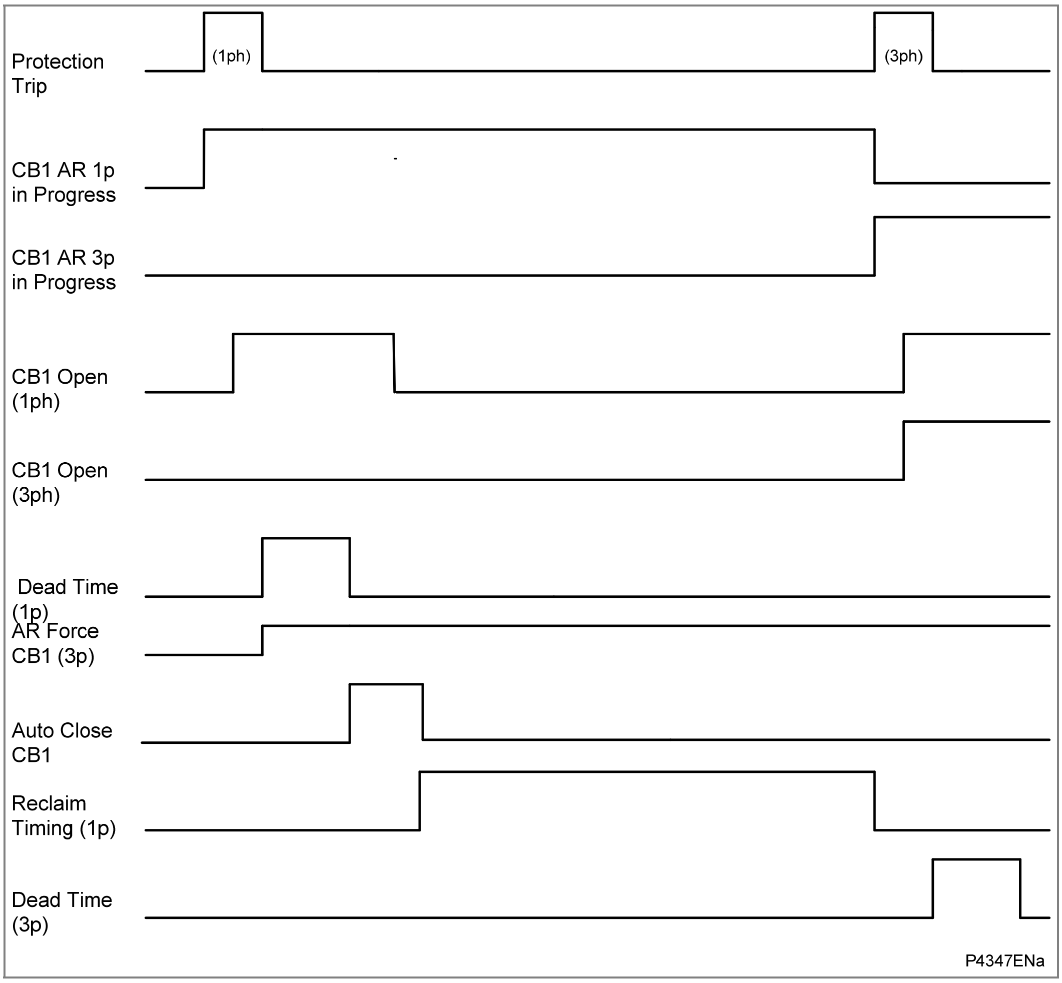

Protection Trip
(1ph)
(3ph)
CB1 AR 1p in Progress
CB1 AR 3p in Progress
CB1 Open (1ph)
CB1 Open (3ph)
Dead Time (1p)
AR Force CB1 (3p)
Auto Close CB1
Reclaim Timing (1p)
Dead Time (3p)
P4347ENa

Figure 116 - Auto-reclose timing diagram - repeated fault inception

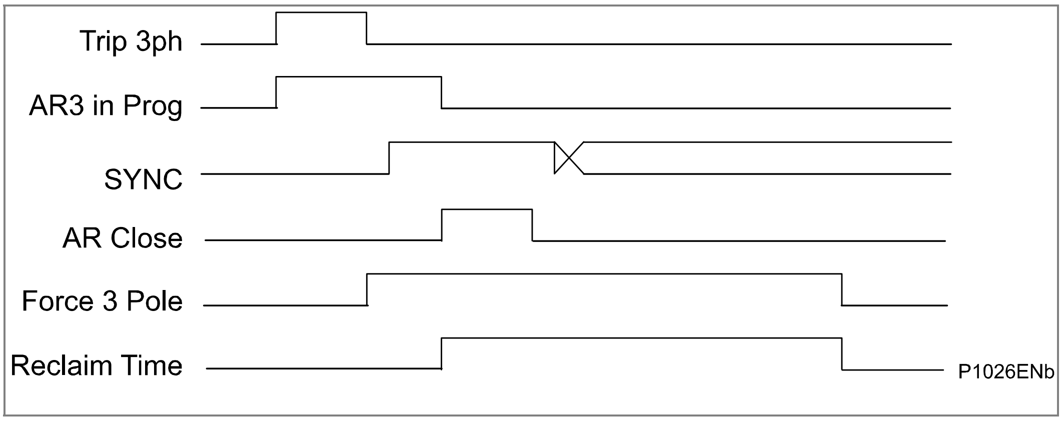


Figure 117 - Auto-reclose timing diagram - fault with system synchronism

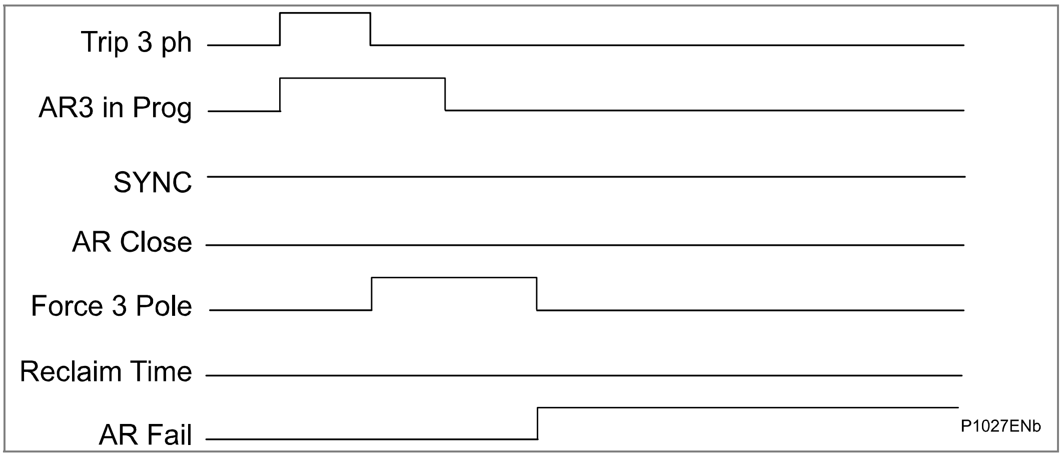


Figure 118 - Auto-reclose timing diagram - lockout for no checksynch

4.6.6 P446 Auto-Reclose - Main Operating Features

4.6.6.1 P446 Circuit Breaker In Service

The circuit breaker in service logic is shown in Figure AR 122 (logic diagram supplement).

To be available for auto-reclosing, each circuit breaker has to be "**in service**" when the auto-reclose is initiated by a protection operation. The circuit breaker is considered to be "**in service**" if it has been in a closed state for a period equal to or greater than the setting "**CB IS Time**".

A short adjustable time delay, "**CB IS Memory Time**", allows for situations where, due to very fast acting circuit breaker auxiliary switches, when a circuit breaker trips following a fault, the circuit breaker change of state from closed to open is detected in the auto-reclose initiation logic before the "**AR Initiate**" signal from the protection is recognized.

Once an auto-reclose cycle has been started for the relevant circuit breaker, the "**in service**" signal for that circuit breaker stays set until the end of the auto-reclose cycle.

The "**CBx In Service**" (x = 1 or 2) signal resets if the circuit breaker opens, or if the corresponding circuit breaker Auto-Reclose In Progress (ARIP) signal resets.

4.6.6.2 P446 Auto-Reclose Enable

The auto-reclose enable logic is shown in Figure AR 123 (logic diagram supplement).

A master enable/disable signal provides overall control of the auto-reclose function for the circuit breakers. If the "**Auto-reclose**" setting cell in the CONFIGURATION column of the menu is set to "**enabled**" the auto-recloser can be brought into service with other commands (described below) providing further control.

In the figure, the auto-recloser is enabled when the "**AR In Service**" DDB (1385) is driven high. To achieve this, as well as enabling the "**Auto-reclose**" setting cell in the CONFIGURATION column of the menu, conditions 1 and 2 below must be met:

1. Auto-reclose must be enabled for at least one of the circuit breakers (CB1/CB2). This is achieved by enabling DDB input "**AR Enable CB1**" (1609) for CB1 and/or "**AR Enable CB2**" (1605) for CB2. Both these DDBs signals default to "**high**" if not mapped in the PSL so, if they are not mapped, this part of the logic will always be satisfied.
2. Auto-reclosing needs to be enabled from an opto input mapped to the "**AR Enable**" DDB (1384), or one of the following 3 conditions must be met:
    - A menu command from the HMI "**Auto-reclose Mode**" cell in the CB CONTROL column of the menu is used to bring the auto-recloser into service, or,
    - For a P446 having IEC 60870-5-103 communications, a standardized enable auto-reclose command is received via the communications link, or,
    - The auto-recloser is brought into service by the pulsing of the "**AR Pulse On**" DDB (1382).

The result of the logic above is the auto-reclose status. This can be seen in the data cell "**AR Status**" in the CB CONTROL column of the menu, and will be either "**In Service**" or "**Out of Service**".

4.6.6.3 P446 Leader & Follower Circuit Breaker Selection

The leader and follower circuit breaker selection logic is shown in Figure AR 124 (logic diagram supplement).

The method of selecting the preferred leader and follower circuit breakers is determined by the menu setting "**Leader Select By:**", which can be set to "**Leader by Menu**", "**Leader by Opto**" or "**Leader by Ctrl**".

If "**Leader Select By:**" is set to "**Leader by Menu**", a further setting, "**Select Leader:**", becomes visible and is used to select the preferred leader circuit breaker by setting "**Select Leader:**" either to "**Sel Leader CB1**" or "**Sel Leader CB2**".

If "**Leader Select By:**" is set to "**Leader by Opto**", the preferred leader circuit breaker is determined by the status of the input DDB (1408): "**CB2 Lead**". If the input DDB (1408) "**CB2 Lead**" is low, then preferred leader circuit breaker is CB1. If DDB "**CB2 Lead**" is high then it selects CB2 as the preferred leader.

If "**Leader Select By:**" is set to "**Leader by Control**", then the preferred leader circuit breaker is determined by the user control command "**CTRL CB2 Lead**" cell found under the CB CONTROL column in the relay menu. If the command applied is "**Reset CB2 Lead**", CB1 is selected as the preferred leader. Applying "**Set CB2 Lead**" command selects CB2 as the preferred leader.

If "**Num CBs**" is set to "**Both CB1 &CB2**", either CB1 or CB2 can be selected as leader. If the setting "**Num CBs**" is set to "**CB1 Only**", CB1 is selected as leader. Similarly, CB2 is selected as leader if the setting "**Num CBs**" is set to "**CB2 Only**".

Provided that the circuit breaker is available for auto-reclose (i.e. the circuit breaker is: "**in service**", not locked out, and enabled for auto-reclosing {refer to sections 4.6.6.2 and 4.6.6.4}), the "**preferred**" leader circuit breaker will be the "**active**" leading circuit breaker in the auto-reclose cycle.

If the “**preferred**” leader circuit breaker is not available for auto-reclosing then, provided it is available for auto-reclose, the “**non-preferred**” circuit breaker becomes the “**active**” leader. If this is the case there will be no follower circuit breaker.

If both circuit breakers are available for auto-reclosing and follower re-closing is enabled, then the “**preferred leader**” will be the “**active**” leader and the “**non-preferred**” circuit breaker will be the follower.

4.6.6.4 P446 Auto-Reclose Mode for Leader & Follower Circuit Breaker

The auto-reclose mode for the leader and follower circuit breaker logic is shown in Figure AR 125 (logic diagram supplement).

Once auto-reclosing is enabled, the specific re-closing modes which can be applied to each circuit breaker are selected.

The auto-reclose function has three operating modes:

- Single Phase Auto-reclose (1P)
- Three Phase Auto-reclose (3P)
- Single/Three Phase Auto-reclose(1/3P)

Single phase re-closing is permitted only for the first shot of an auto-reclose cycle. If two or more shots are enabled, then, in a multi-shot auto-reclose cycle, the second and subsequent trips and re-closures will always be three phase.

The settings for the re-closing modes are affected by the number of circuit breakers, “**Num CBs**”, setting in the AUTO-RECLOSE column of the menu.

4.6.6.4.1 P446 Auto-Reclose Mode with One Circuit Breaker

If “**Num CBs**” is set to “**CB1 Only**” or “**CB2 Only**”, only one circuit breaker will be controlled, and a setting “**AR Mode**” is visible which controls the specific auto-reclosing mode for the active circuit breaker.

The following setting options are available: “**AR 1P**”, “**AR 1/3P**”, “**AR 3P**” & “**Opto**”.

Single phase auto-reclosing of the circuit breaker is permitted if “**AR Mode**” is set to “**AR 1P**” or “**AR 1/3P**”. Three phase auto-reclosing of the circuit breaker is permitted if “**AR Mode**” is set to “**AR 3P**” or “**AR 1/3P**”.

If the “**AR Mode**” selection is by “**Opto**” then the re-close mode for the active circuit breaker is determined by the status of two DDB inputs: “**Lead AR 1P**” (1497) to enable single phase auto-reclose, and “**Lead AR 3P**” (1498) to enable three phase auto-reclose.

4.6.6.4.2 P446 Auto-Reclose Mode with Two Circuit Breakers

If “**Num CBs**” is set to “**Both CB1&CB2**” then a setting “**Lead/Foll ARMode**” becomes visible and is used to control the specific re-closing modes that are applied to each circuit breaker. The options available are:

- “L1P F1P”
- “L1P F3P”
- “L3P F3P”
- “L1/3P F1/3P”
- “L1/3P F3P”
- “Opto”

Where L refers to the leader circuit breaker, F refers to the follower circuit breaker, 1P implies single phase, 3P implies three phase, and 1/3P implies single or three phase, so a setting of "**L1/3P F3P**" would mean that the leader circuit breaker could perform single or three phase auto-reclose, whilst the follower would perform three phase auto-reclose only.

If the auto-reclose mode selection is by "**Opto**" then the re-close mode for the active leader is determined by the status of two DDB inputs: "**Lead AR 1P**" (1497) to enable single phase auto-reclose, and "**Lead AR 3P**" (1498) to enable three phase auto-reclose. The re-close mode for the active follower is determined by the status of two DDB inputs: "**Follower AR 1P**" (1409) to enable single phase auto-reclose, and "**Follower AR 3P**" (1410) to enable three phase auto-reclose.

Where the selected follower auto-reclose mode supports single phase tripping, the follower can perform single phase auto-reclose only if the leader circuit breaker has performed single phase auto-reclose. If the leader has tripped and re-closed three phase, the follower is also forced to trip three phase. The follower will re-close three phase provided three phase auto-reclose is permitted for the follower circuit breaker. If the follower circuit breaker trips three phase and three phase auto-reclose is not permitted for the follower, then the follower circuit breaker locks out without re-closing.

4.6.6.5 P446 Force Three Phase Trip

The "**force three phase trip**" logic is shown in Figure AR 126 (logic diagram supplement).

Following single phase tripping, whilst the auto-reclose cycle is in progress, and upon resetting of the protection elements, an output signal DDB associated with the tripped circuit breaker is asserted high.

In the case of CB1, this is DDB: "**AR Force CB1 3P**" (858).

In the case of CB2, this is DDB: "**AR Force CB2 3P**" (1485).

These signals are applied to any associated protection trip conversion logic to force all protection trips to be converted to three phase trips for the associated circuit breaker, for any subsequent faults that occur whilst the auto-reclose cycle remains in progress.

4.6.6.6 P446 Auto-Reclose Initiation

The auto-reclose initiation logic is shown in Figure AR 127 to Figure AR 130 (logic diagram supplement).

Auto-reclose cycles can be initiated by:

- Protection functions hosted by the P446
- External protection equipment
- Trip test

Auto-reclose initiation will start an auto-reclose for any circuit breaker that is in service and enabled for auto-reclose: CB1 auto-reclose will start if CB1 is in service and enabled for auto-reclose; CB2 auto-reclose will start if CB2 is in service and enabled for auto-reclose.

When an auto-reclose cycle is started, the relevant circuit breaker auto-reclose in progress "**CB1 ARIP**" and/or "**CB2 ARIP**" signal is set, and remains set until the end of the cycle for the associated circuit breaker. The end of the cycle is signified by successful re-closure, or by lockout.

4.6.6.6.1 P446 Auto-Reclose Initiation by Host Relay protection Function

Many protection functions in the P446 (for example Zone 1 trips, distance-aided scheme trips, time-delayed distance zones, overcurrent and earth (ground) elements, DEF and directional aided schemes) can be programmed to initiate or block auto-reclose by selecting the "**Initiate AR**", or "**Block AR**" options in the settings which are available under the "**AUTORECLOSE**" settings column of the menu. Operation of a protection function selected for auto-reclose will initiate auto-reclose. Operation of a protection function selected to block auto-reclose will block auto-reclose and, if an auto-reclose is already in progress, it will force a lockout.

4.6.6.6.2 P446 Auto-Reclose Initiation by External Protection Equipment

The following DDB signals are available for mapping in the PSL from opto inputs or communication inputs to initiate auto-reclosing.

- DDB (535): "CB1 Ext Trip A"
- DDB (536): "CB1 Ext Trip B"
- DDB (537): "CB1 Ext Trip C"
- DDB (534): "CB1 Ext Trip 3Ph"
- DDB (539): "CB2 Ext Trip A"
- DDB (540): "CB2 Ext Trip B"
- DDB (541): "CB2 Ext Trip C"
- DDB (538): "CB2 Ext Trip 3Ph"

If mapped, activation of the input to the DDB will initiate auto-reclose.

4.6.6.6.3 P446 Auto-Reclose Initiation and Cycle by Trip Test

A user command ("**Test Autoreclose**" under COMMISSION TESTS) in the P446 menu can be used to initiate an auto-reclose cycle. Four separate commands can be executed, each command comprising a 100ms pulse output when the relevant "**execute**" option is selected. Available commands are: "**Trip Pole A**"/"**Trip Pole B**"/"**Trip Pole C2**/"**Trip 3 Pole**". There is also a "**No Operation**" option to exit the command field without initiating a test.

4.6.6.7 P446 Sequence Counter

The sequence counter logic is shown in Figure AR 131 (logic diagram supplement).

The auto-reclose logic includes a counter known as the sequence counter. Unless auto-reclose is in progress, the sequence counter will have a value of 0. Following a trip, and subsequent auto-reclose initiation, the sequence counter is incremented. The counter provides output signals indicating how many initiation events have occurred in any auto-reclose cycle. These signals are available as user indications and are used in the logic to select the appropriate dead timers or, for a persistent fault, force a lockout.

The logic generates the following sequence counter outputs which are used in the auto-reclose shots counter logic (refer section 4.6.6.14).

- DDB 847: "**Seq. Counter = 1**" is set when the counter is at 1;
- DDB 848: "**Seq. Counter = 2**" is set when the counter is at 2;
- DDB 849: "**Seq. Counter = 3**" is set when the counter is at 3; and
- DDB 850: "**Seq. Counter = 4**" is set when the counter is at 4.

Every time the relay trips the sequence counter is incremented by 1. The auto-reclose logic compares the sequence counter values to the number of auto-reclose shots setting, “**AR Shots**”. If the counter value exceeds the setting then the auto-reclose is locked out.

In the case of a successful auto-reclose cycle the sequence counter resets to zero.

4.6.6.8 P446 Auto-Reclose Cycle Selection

The auto-reclose cycle selection determines, for a dual breaker configuration, the logic to determine which of the circuit breakers will act as leader/follower and whether the re-closing will be single phase or three phase. The logic is shown in Figure AR 132 and Figure AR 133 (logic diagram supplement).

In a dual circuit breaker arrangement, when an auto-reclose cycle is started, single phase or three phase re-closing is asserted for each circuit breaker, according to whether the circuit breaker has tripped single phase or three phase, and according to whether single phase and/or three phase re-closing is permitted for that circuit breaker. Dependent upon the settings and trip performed, each circuit breaker can perform:

- Single phase re-close as Leader (with or without follower);
- Single phase re-close as Follower (provided the leader is also selected to single phase auto-reclose);
- Three phase re-close as Leader (with or without follower);
- Three phase re-close as Follower.

4.6.6.9 P446 Dead Time Control

The dead time control logic is shown in Figure AR 134 to Figure AR 137 (logic diagram supplement).

Once an auto-reclose cycle has started, the conditions to enable the dead time to run are determined by menu settings, circuit breaker status, protection status, the nature of the auto-reclose cycle (single phase or three phase) and opto inputs from external sources.

Three settings are involved in controlling the dead time start:

- “DT Start by Prot”
- “3PDTStart WhenLD”
- “DTStart by CB Op”.

The “**DT Start by Prot**” setting is always visible and has three options “**Protection Reset**”, “**Protection Op**”, and “**Disable**”. These options set the basic conditions for starting the dead time.

The ‘**dead time started by protection operation**’ condition can, optionally, be qualified by a check that the line is dead.

The ‘**dead time started by protection reset**’ condition can, optionally, be qualified by a check,, that the circuit breaker is open, as well as by an optional check that the line is dead (note*).

If the “**DT Start by Prot**” is set to “**Disable**”, the circuit breaker must be open for the dead time to start. This condition can, optionally be qualified by a check that the line is dead (note*).

The qualification to check that the ‘**line is dead**’ is provided by setting “**3PDTStart WhenLD**” to “**Enabled**”.

The qualification to check that the ‘**circuit breaker is open**’ is provided by setting “**DTStart by CB Op**” to “**Enabled**”.

In a dual circuit breaker scheme ("**Num CBs**" set to "**Both CB1 & CB2**") if the "**DTStart by CB Op**" is set to enabled, both circuit breakers must be tripped to enable the dead time to start. For a single phase auto-reclose cycle, the leader circuit breaker has to be tripped single phase. For a three phase auto-reclose cycle, both circuit breakers have to be tripped three phase.

Note: This is only applicable when tripping/auto-reclose is three phase.*

4.6.6.10 P446 Follower Circuit Breaker Enable and Time Control

The follower circuit breaker control logic is shown in Figure AR 138 to Figure AR 140 (logic diagram supplement).

When a leader/follower auto-reclose cycle is initiated, the conditions for the follower delay period ("**Follower Time**") to start are determined by the leader circuit breaker operation, the follower circuit breaker status, the menu setting "**BF if LFail Cls**" (Block Follower re-close if Leader CB Fails to close), and opto inputs from external sources. The basic condition to start the follower delay is that the leader circuit breaker must have re-closed.

If the menu setting "**BF if LFail Cls**" is set to "**Disabled**", the follower circuit breaker will re-close even if the leader circuit breaker fails to re-close (for example, due to the absence of a "**CB Healthy**" signal). When "**BF if LFail Cls**" is set to "**Disabled**", an additional menu setting "**Dynamic F/L**" becomes visible to further control the operation of the follower circuit breaker. If the setting "**Dynamic F/L**" is set to "**Enabled**", the follower circuit breaker will re-close with no deliberate additional delay, i.e. at approximately the same instant that the leader circuit breaker would have closed if it had been healthy. If the menu setting "**Dynamic F/L**" is set to "**Disabled**", the follower circuit breaker will re-close after an additional delay equal to the set "**Follower Time**".

If the menu setting "**BF if LFail Cls**" is set to "**Enabled**" then, if the leader circuit breaker fails to re-close, the follower circuit breaker cycle is cancelled and auto-reclosing of both circuit breakers is locked out.

The follower circuit breaker must be open for the follower delay time to start. For a single phase follower auto-reclose cycle, the follower circuit breaker has to be open single phase. For a three phase follower auto-reclose cycle, the follower circuit breaker has to be open three phase.

When the follower delay time has timed out, the relevant internal signal "**CBxSPFTCOMP**" or "**CBx3PFTCOMP**" (x = 1 or 2) is applied to the "**CB AutoClose**" logic, described later in section 4.6.6.11 to indicate that the follower time is complete.

4.6.6.11 P446 CB1 and CB2 Auto Close

The CB1 and CB2 auto close logic is shown in Figure AR 141 to Figure AR 142 (logic diagram supplement).

When the end of a dead time or the end of a follower time is indicated by one of the following internal signals, the auto close logic is executed:

- "CB1 SPDTCOMP"
- "CB1 3PDTCOMP"
- "CB2 SPDTCOMP"
- "CB2 3PDTCOMP"
- "CB1 SPFTCOMP"
- "CB1 3PFTCOMP"
- "CB2 SPFTCOMP"

- “CB2 3PFTCOMP”

The auto close logic checks that all necessary conditions are satisfied before issuing a “**AutoClose CB1**” or “**AutoClose CB2**” signal to the CB1 and CB2 overall control scheme as shown in the AR Figures 33 & 34 (logic diagram supplement) described in section 4.5.

For any re-closure, the circuit breaker must be healthy (mechanism OK to close, and re-trip if necessary) and it should not be in a lockout state.

For any single phase re-closure, the circuit breaker must be open on one phase. For any three phase re-closure, the circuit breaker must be open on all three phases and the appropriate system check conditions (live bus/dead line, synch check etc.) must be satisfied. The system check conditions for CB1 leader re-close, CB2 leader re-close, CB1 follower re-close and CB2 follower re-close are independently selectable by menu settings and are described in section 4.6.6.15.

The auto close signals (“**AutoClose CB1**”, “**AutoClose CB2**”) sent to the circuit breaker control scheme are pulses lasting 100 milliseconds. Another pair of signals “**Set CB1 Close**” & “**Set CB2 Close**”, DDBs (1565/1449) are set in conjunction with the auto close signals, but these remain set until either the end of the auto-reclose cycle, or the next protection operation. These signals are used to initiate the “**Reclaim timing logic**” and the “**CB AR Shots Counters**” logic, described in sections 4.6.6.12 to 4.6.6.14.

4.6.6.12 P446 Reclaim Time & Successful Auto-Reclose

The reclaim time logic is shown in Figure AR 143 to Figure AR 144 to (logic diagram supplement).

The successful auto-reclose logic is shown in Figure AR 145 to Figure AR 147 (logic diagram supplement).

The “**Set CB1 Close**” & “**Set CB1 Close**”, DDBs (1565/1449) signals from the auto close logic are used to enable the reclaim timers. Depending on whether the circuit breaker has tripped single phase or three phase, and whether single phase and/or three phase re-closing is permitted for the circuit breaker, either the single phase reclaim timer “**SPAR Reclaim Time**” or the three phase reclaim timer “**3PAR Reclaim Time**” is enabled.

If any protection re-operates before the reclaim time has timed out, the sequence counter is incremented. The counter signal advances from ‘**Seq Counter = n**’ to ‘**Seq Counter = (n+1)**’, resets any **“….DTCOMP**” signal and prepares the logic for the next dead time to start when conditions are suitable. The operation also resets the “**Set CB Close**” signal, and hence the reclaim timer is also stopped and reset. The “**Reclaim time**” starts again if the “**Set CB Close**” signal goes high following completion of a dead time in a subsequent auto-reclose cycle.

If CB1 is closed and has not tripped again when the reclaim time is complete, signals “**CB1 Succ 1P AR**”, (DDB1571) or “**CB1 Succ 3P AR**”, (DDB 852) are generated to indicate the successful re-closure.

Similarly, If CB2 is re-closed during the auto-reclose cycle and remains closed when the reclaim time is complete, signals “**CB2 Succ 1P AR**”, (DDB 1451) or “**CB2 Succ 3P AR**”, (DDB 1452) are generated to indicate successful re-closure.

These signals also increment the relevant circuit breaker successful auto-reclose shot counters and reset the relevant “**CB ARIP**” signal.

The “**successful auto-reclose**” signals generated from the logic can be reset by various commands and settings options available under CB CONTROL menu settings column.

These settings are described as follows:

If “**Res AROK by UI**” is set to enabled, all the “**successful auto-reclose**" signals can be reset by user interface command “**Reset AROK Ind**” from the CB CONTROL settings column.

If “**Res AROK by NoAR**” is set to enabled, the “**successful auto-reclose**" signals for each circuit breaker can be reset by temporarily generating an “**AR disabled**” signal for each circuit breaker according to the logic described in section 4.6.6.2, “**Autoreclose Enable**” logics, Figure AR 124.

If “**Res AROK by Ext**” is set to enabled, the “**successful autoreclose**" signals for can be reset by activation of the relevant input “**Ext Rst CB1 AROK**” or “**Ext Rst CB2 AROK**” (DDB1517 or 1417) mapped in the PSL.

If “**Res AROK by TDly**” is set to enabled, the “**successful autoreclose**" signals for are automatically reset after a user defined time delay as set in "**Res AROK by TDly**" setting.

4.6.6.13 P446 Circuit Breaker Healthy and System Check Timers

The circuit breaker healthy and system check timers logic is shown in Figure AR 148 and Figure AR 149 (logic diagram supplement).

This logic provides signals to cancel auto-reclosing for either circuit breaker if the circuit breaker is not healthy (e.g. low gas pressure or, for three phase auto-reclosing, the required line & bus voltage conditions are not satisfied) when the scheme is ready to close the circuit breaker.

In this logic, both CB1 and CB2 share the settings “**AR CBHealthy Time**” and “**AR CheckSync Time**”.

For either circuit breaker, at the completion of any dead time or follower time, the logic starts an “**AR CBHealthy timer**”. If the “**CB Healthy**” signal (DDB 436 or 437) becomes high before the set time is complete, the timer stops and, if all other relevant circuit breaker closing conditions are satisfied the scheme issues the “**CB AutoClose**” signal. If the “**CB Healthy**” signal, (DDB 436 or 437) signal stays low, then at the end of the set “**AR CBHealthy time**” an “**AR CB Unhealthy**” alarm signal (DDB 307 or 329) is set. This forces the circuit breaker auto-reclose sequence to be cancelled.

Additionally, for either circuit breaker, at the completion of any three phase dead time or three phase follower time, the logic starts an “**AR CheckSync Time**”. If the circuit breaker synchro-check OK signal {“**CB L SCOK**“ (DDB 1573 or 1455) or “**CB F SCOK**” (DDB1491 or 1456)} goes high before the set time is complete, the timer stops and, if all other relevant circuit breaker closing conditions are satisfied, the scheme issues the “**CB AutoClose**” signal. If the “**System check OK**” signal stays low, then at the end of the “**AR CheckSync Time**” an alarm “**AR CB No C/S**” (DDB 308 or 330) is set which informs that the check synchronism is not satisfied for that circuit breaker and forces the auto-reclose sequence to be cancelled.

4.6.6.14 P446 CB1 & CB2 Auto-Reclose Shots Counters

The CB1 & CB2 auto-reclose shots counter logic is shown in Figure AR 150 and Figure AR 151 (logic diagram supplement).

A number of counters are provided to enable analysis circuit breaker auto-reclosing history. Each circuit breaker has a set of counters that are stored in non-volatile memory, so that the data is maintained even in the event of a failure of the auxiliary supply.

Logic signals from the “**Sequence counters**” is combined with “**successful auto-reclose**” signals and “**auto-reclose lockout**” signals to provide the following summary for each circuit breaker:

Overall total shots (No. of re-close attempts);

- “CBx Total Shots”

Number of successful single phase re-closures;

- “CBx SUCC SPAR”

Number of successful 1st shot three phase re-closures;

- “CBx SUCC3PARShot1”

Number of successful 2nd shot three phase re-closures;

- “CBx SUCC3PARShot2”

Number of successful 3rd shot three phase re-closures;

- “CBx SUCC3PARShot3”

Number of successful 4th shot three phase re-closures;

- “CBx SUCC3PARShot4”

Number of failed auto-reclose cycles which forced CB to lockout.

- “CBx Failed Shots”

All the counter contents are accessible through the CB CONTROL column of the menu.

For each individual circuit breaker, these counters can be reset either by user commands “**Reset CB1 Shots**” or “**Reset CB2 Shots**” from the CB CONTROL settings column, or by activation of the relevant input “**Ext Rst CB1 Shots**” or “**Ext Rst CB2 Shots**” (DDB 1518 or 1418) mapped in the PSL.

4.6.6.15 P446 System Checks for Circuit Breaker Closing

The system checks for circuit breaker closing logic is shown in Figure AR 152 to Figure AR 157 (logic diagram supplement).

For three phase auto-reclosing and control closing of the circuit breakers, system voltage checks are separately selectable for:

- CB1 re-closing as leader;
- CB1 re-closing as follower;
- CB1 control close;
- CB2 re-closing as leader;
- CB2 re-closing as follower;
- CB2 control close.

In the AUTORECLOSE settings, if the “**Num CBs**” is set to “**CB1 Only**” or “**CB2 Only**”, then the operation of the circuit breaker will be the same as described for the corresponding leader circuit breaker (for example CB1 operation will be the same as described by CB1L in the diagrams and descriptions.

The system check options for each circuit breaker are enabled or disabled in the “**CBx SC all**” setting (x = 1L, 2L, 1F, 2F) in the AUTORECLOSE column of the menu. If set to “**Disabled**”, then no system checks are required on any shot, and the relevant settings are invisible. Otherwise, the system check options that can be enabled for each breaker (as leader or follower) are:

System Check Option	Setting
System checks not required for first shot of auto-reclose	“CBx SC Shot1”
Fast synchronism check (note 2)	“CBx SC ClsNoDly”
Check synchronism stage 1 (note 1)	“CBx SC CS1”
Check synchronism stage 2 (note 1)	“CBx SC CS2”
Dead line/Live bus	“CBx SC DLLB”
Live line/Dead bus	“CBx SC LLDB”

System Check Option	Setting
Dead line/Dead bus	“CBx SC DLDB”

Note 1	*Two separate (independent) system synchronism check stages are available for each circuit breaker. Each stage has different slip frequency and phase angle settings as described in section 4.7.*
Note 2	*A “**fast synchronism check auto-reclose**” option is available for the three phase auto-reclose as leader circuit breaker, by menu setting “**CBx SC ClsNoDly**”. When the setting is enabled, then if the line and bus come into synchronism (i.e. line energized from remote end) at any time after the three phase dead time has started, an “**AutoClose CB**” signal is issued immediately without waiting for the dead time to elapse. This option is sometimes required for the second line end to reclose on a line with delayed auto-reclosing (typical cycle: first line end reclose after dead time with live bus and dead line, then second line end reclose immediately with live bus and live line in synchronism).*

Table 28 - System check options and settings

Manual re-closing for each circuit breaker is controlled according to the settings in the SYSTEM CHECKS column of the menu. The system check options for each circuit breaker are enabled or disabled in the “**CBxM SC all**” setting (x = 1 or 2) in the SYSTEM CHECKS column of the menu. If set to “**Disabled**”, then no system checks are required for manual closure, and the relevant settings are invisible. Otherwise, the system check options that can be enabled for each breaker (as leader or follower) are:

System Check Option	Setting
Check synchronism stage 1 (refer to note 1 above)	“CBxM SC CS1”
Check synchronism stage 2 (refer to note 1 above)	“CBxM SC CS2”
Dead line/Live bus	“CBxM SC DLLB”
Live line/Dead bus	“CBxM SC LLDB”
Dead line/Dead bus	“CBxM SC DLDB”

Table 29 - System check options and settings

4.6.6.16 P446 CB1 & CB2 Trip Time Monitor

The circuit breaker trip time monitor logic is shown in Figure AR 158 and Figure AR 159 (logic diagram supplement).

This logic checks that a circuit breaker trips correctly following the issuing of a protection trip signal.

When any protection trip signal is issued a timer, “**Trip Pulse Time**” is started.

The “**Trip Pulse Time**” setting is common to both CB1 and CB2 and is used in the trip time monitor logic and in the circuit breaker control logic.

If the circuit breaker trips correctly (single phase or three phase, according to the trip signal and settings) the timer resets and the auto-reclose cycle, if enabled, proceeds normally. If either circuit breaker fails to trip correctly within the set time, the signal “**CB1 Fail Pr Trip**” (1575) and/or “**CB2 Fail Pr Trip**” (1459) is issued and the affected circuit breaker auto-reclose cycle is forced to lock out.

4.6.6.17 P446 Auto-Reclose Lockout

The auto-reclose lockout logic is shown in Figure AR 160 to Figure AR 163 (logic diagram supplement).

Auto-reclose lockout of a circuit breaker will be triggered by a number of events. These are outlined below:

- Protection operation during reclaim time. If, following the final re-close attempt, the protection operates during the reclaim time, the relay will be driven to lockout and the auto-reclose function will be disabled until the lockout condition is reset.
- Persistent fault. A fault is considered persistent if the protection re-operates after the last permitted shot.
- Block auto-reclose. The block auto-reclose logic can cause a lockout if auto-reclose is in progress. If asserted, the "**Block CBx AR**" input (DDB 448/1421) mapped in the PSL will, if auto-reclose is in progress, block auto-reclose and cause a lockout.
- Multi phase faults. The logic can be set to block auto-reclose either for two phase or three phase faults, or to block auto-reclose for three phase faults only. For this, the setting "**Multi Phase AR**" applies, where the options are "**Allow AR**", "**BAR 2&3 Phase**" and "**BAR 3 Phase**" in the AUTORECLOSE column of the menu.
- Protection function selection. The protection functions can be individually selected to block auto-reclose and force lockout. If enabled, the protection functions in the AUTORECLOSE column of the menu can be set to "**Block AR**". Selecting "B**lock AR**" will cause a lockout if the particular protection function operates.
- Circuit breaker failure to close. If the circuit breaker fails to close because, for example, the circuit breaker springs are not charged, the gas pressure is low, or there is no synchronism between the system voltages indicated by the "**AR CBx Unhealthy**" and "**AR CBx No Checksync**" alarms, auto-reclose will be blocked and forced to lockout.
- Circuit breaker open at the end of the reclaim time. An auto-reclose lockout is forced if the circuit breaker is open at the end of the reclaim time.
- Circuit breaker fails to close when the close command is issued.
- Block follower if leader fails to close is set. If the setting "**BF if Lfail Cls**" in the AUTORECLOSE column of the menu is set to "**Enable**", the active follower circuit breaker will lockout if the leader circuit breaker fails to re-close.
- Circuit breaker fails to trip correctly.
- Three phase dead time started by line dead violation. If the line does not go dead within the "**Dead Line Time**" time setting when the dead time start is determined by the menu setting "**3PDTStart WhenLD**", the logic will force the auto-reclose sequence to lockout after expiry of the setting time.
- Single phase evolving to multi phase fault. If, after expiry of the discriminating time from the "**Protection Re-operation + Evolving**" fault logic (refer to section 4.6.6.8), a single phase fault evolves into a two, or three phase fault, the internal signal "**Evolve Lock**" will be asserted that will force the auto-reclose to lockout.
- Leader/Follower invalid selection via opto. If the "**Leader/Follower AR**" mode in the AUTORECLOSE menu is set to be selected via the opto-inputs, "**Opto**", then if the logic detects an invalid auto-reclose mode combination selection, it will force both CB1 and CB2 to lockout if a trip occurs.

If CB1 or CB2 is locked out, the logic generates the alarms "**CBx AR Lockout**" (DDB 306/328) for the corresponding circuit breaker. In this condition, auto-reclose of the circuit breaker cannot be initiated until the corresponding lockout has been reset. The methods of resetting from the lockout state are discussed in the next section.

Note	*Circuit breaker lockout, can also be caused by the circuit breaker condition monitoring functions:*

- Maintenance lockout,
- Excessive fault frequency lockout,

- Broken current lockout,
- Circuit breaker failed to trip,
- Circuit breaker failed to close,
- Manual close failure - no check synchronism/circuit breaker unhealthy situation.

These lockout alarms are mapped to a signals “**CBx mon LO Alarm**” (DDBs 300 and 322 for CB1 and CB2 respectively) and “**CBx LO Alarm**”. (DDBs 860 and 1599 for CB1 and CB2 respectively).

4.6.6.18 P446 Reset Circuit Breaker Lockout

The lockout conditions caused by the circuit breaker condition monitoring functions (including manual close failure) described in section 4.6.6.17 can be reset according to the condition of the “**Rst CB mon LO by**” setting found in the CB CONTROL column of the menu.

The “**Rst CB mon LO by**” setting has two options “**CB Close**”, and “**User interface**”.

If “**Rst CB mon LO By**” is set to “**CB Close**” then closure of the circuit breaker will be a trigger for lockout reset. If set to “**CB Close**”, a further setting, “**CB mon LO RstDly**”, becomes visible. This is a timer setting that is applied between the circuit breaker re-closing, and the lockout being reset.

If “**Rst CB mon LO By**” is set to “**User Interface**” then a further command appears in the CB CONTROL column of the menu, “**CB mon LO reset**”. This command can be used to reset the lockout.

This logic is included in Figure AR 164.

An auto-reclose lockout state of a circuit breaker will generate an auto-reclose circuit breaker lockout alarm (“**AR CBx lockout**”) and DDB 306 or 328 is set, corresponding to CB1 or CB2 being locked out, as per the logic diagrams in Figure AR 164 and Figure AR 165.

The auto-reclose lockout conditions can be reset by various commands and settings options found under the CB CONTROL column of the menu.

These settings and commands are described below:

- If “**Res LO by CB IS**” is set to “**Enabled**”, the circuit breaker lockout is reset if the circuit breaker is manually closed successfully. For this the circuit breaker must remain closed long enough so that it enters the “**In Service**” state. (See section 4.6.6.1, “**Circuit Breaker In Service**” and 0).
- If “**Res LO by UI**” is set to “**Enabled**”, the circuit breaker lockout can be reset by the user interface commands “**Reset CB1 LO**” or “**Reset CB2 LO**” found in the CB CONTROL column of the menu.
- If “**Res LO by NoAR**” is set to “**Enabled**”, the circuit breaker lockout can be reset by temporarily generating an “**AR disabled**” signal according to the logic described in section 4.6.6.2, “**Auto-reclose Enable**” logic and Figure AR 123.
- If “**Res LO by ExtDDB**” is set to “**Enabled**”, the circuit breaker lockout can be reset by activation of the relevant input DDB “**Rst CB1 Lockout**” or “**Rst CB2 Lockout**” (DDB 446/1422) mapped in the PSL.
- If “**Res LO by TDelay**” is set to “**Enabled**”, the circuit breaker lockout is automatically reset after a user defined time delay as set in “**LO Reset Time**” setting.

The reset circuit breaker auto-reclose lockout logic is shown in Figure AR 166 and Figure AR 167 (logic diagram supplement).

4.7 P446 Dual CB System Voltage Checks

4.7.1 P446 Dual CB System Checks Overview

In some situations it is possible for both "**bus**" and "**line**" sides of a circuit breaker to be live when the circuit breaker is open, for example at the ends of a feeder which has a power source at each end. Therefore, when closing the circuit breaker, it is normally necessary to check that the network conditions on both sides are suitable, before giving a CB Close command. This applies to both manual circuit breaker closing and auto-reclosure. If a circuit breaker is closed when the line and bus voltages are both live, with a large phase angle, frequency or magnitude difference between them, the system could be subjected to an unacceptable shock, resulting in loss of stability and possible damage to connected machines.

System checks involve monitoring the voltages on both sides of a circuit breaker, and, if both sides are live, performing a synchronism check to determine whether the phase angle, frequency and voltage magnitude differences between the voltage vectors, are within permitted limits.

The pre-closing system conditions for a given circuit breaker depend on the system configuration and, for auto-reclosing, on the selected auto-reclose program. For example, on a feeder with delayed auto-reclosing, the circuit breakers at the two line ends are normally arranged to close at different times. The first line end to close usually has a live bus and a dead line immediately before re-closing, and charges the line (dead line charge) when the circuit breaker closes. The second line end circuit breaker sees live bus and live line after the first circuit breaker has re-closed. If there is a parallel connection between the ends of the tripped feeder, they are unlikely to go out of synchronism, i.e. the frequencies will be the same, but the increased impedance could cause the phase angle between the two voltages to increase. Therefore the second circuit breaker to close might need a synchronism check, to ensure that the phase angle has not increased to a level that would cause unacceptable shock to the system when the circuit breaker closes.

If there are no parallel interconnections between the ends of the tripped feeder, the two systems could lose synchronism, and the frequency at one end could "**slip**" relative to the other end. In this situation, the second line end would require a synchronism check comprising both phase angle and slip frequency checks.

If the second line end busbar has no power source other than the feeder that has tripped; the circuit breaker will see a live line and dead bus assuming the first circuit breaker has re-closed. When the second line end circuit breaker closes the bus will charge from the live line (dead bus charge).

4.7.2 P446 Dual CB System Voltage Checks Logic Diagrams

The system voltage checks logic is shown in Figure AR 168 to Figure AR 170 (logic diagram supplement).

4.7.3 P446 Dual CB System Voltage Checks VT Selection

The system voltage checks function performs a comparison of the line voltage and the bus voltage.

For a single circuit breaker application, there will be two voltage inputs to compare - one from the Voltage Transformer (VT) input from the line side of the circuit breaker, and one from the VT on the bus side of the circuit breaker.

For a dual circuit breaker installation (breaker-and-a-half switch or mesh/ring bus), three VT inputs are required, one from the common point of the two circuit breakers, identified as the line, one from the bus side of CB1, and the third from the bus side of CB2. In most cases the line VT input will be three phase, whereas the bus VTs will be single phase.

Since the bus VT inputs are normally single phase, the system voltage checks are made on single phases, and since the VT may be connected to either a phase to phase or phase to neutral voltage, then for correct synchronism check operation, the P446 has to be programmed with the appropriate connection. The “**CS Input**” setting in the “**CT AND VT RATIOS**” can be set to “**A-N**”, “**B-N**”, “**C-N**”, “**A-B**”, “**B-C**” or “**C-A**” according to the application.

The single phase Bus1 VT and Bus 2 VT inputs each have associated phase shift and voltage magnitude compensation settings “**CB1 CS VT PhShft**”, “**CB1 CS VT Mag.**”, “**CB2 CS VT PhShft**” and “CB2 **CS VT Mag.**”, to compensate for healthy voltage angle and magnitude differences between the Bus VT input and the selected line VT reference phase. This allows the bus VT inputs to be taken from VT windings with different rated voltages or phase connections to the reference voltage (for example, they could be taken from VTs on opposite sides of a transformer). Any voltage measurements or comparisons using bus VT inputs are made using the compensated values.

The system checks logic comprises two modules, one to monitor the voltages, and one to check for synchronism.

The voltage monitor determines the voltage magnitudes, frequencies and relative phase angles of the VT inputs using the same VT inputs as the check sync reference phase voltage setting “**CS Input**”, The “**Live Line**”, “**Dead Line**”, etc., outputs from the voltage monitor are qualified by blocking inputs from the P446, external VT supervision, VT secondary MCB auxiliary switch contacts, and by external inputs mapped in the PSL to DDBs (1522, etc.) to individually inhibit the output DDBs (888, etc.) for each function.

4.7.4 P446 Dual CB System Voltage Synchronism Checks

Two synchronism check stages are provided for each circuit breaker to compare the line and bus voltages when closing a circuit breaker.

Synchronism check logic is enabled or disabled per circuit breaker, by settings “**Sys Checks CB1**” to “**Enable**” or “**Disable**”, and “**Sys Checks CB2**” to “**Enable**”, or “**Disable**”.

If “**System Checks CB1**” is set to “**Disable**”, all other menu settings associated with system checks and synchronism checks for CB1 become invisible, and a DDB (880) signal “**SChksInactiveCB1**” is set.

Similarly if “**System Checks CB2**” is set to “**Disable**”, all other menu settings associated with system checks and synchronism checks for CB2 become invisible, and a DDB (1484) signal “**SChksInactiveCB2**” is set.

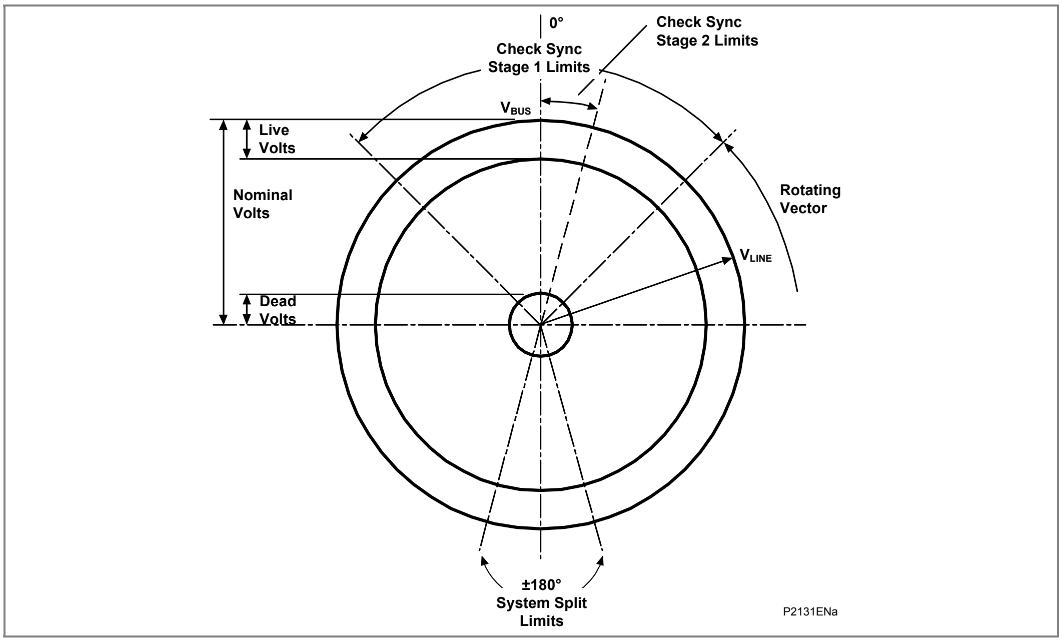

0°
Check Sync
Stage 1 Limits
Check Sync
Stage 2 Limits
V_{BUS}
Live
Volts
Nominal
Volts
Dead
Volts
Rotating
Vector
V_{LINE}
±180°
System Split
Limits
P2131ENa

Figure 119 - Synchro check functionality

The overall check synchronism functionality is illustrated in Figure 119.

4.8 P446 Synchronism Check Functions

Two stages of system synchronism check supervision are provided for each circuit breaker. When required, they control the manual closing and/or auto-reclosing of the associated circuit breaker. “**CB1 CS1**” and “**CB1 CS2**” supervise CB1, whilst “**CB2 CS1**” and “**CB2 CS2**” supervise CB2.

The functionality of the first two stages (“**CB1 CS1**” and “**CB2 CS1**”) is the same for each, but each circuit breaker has individual settings.

The functionality of the second two stages (“**CB1 CS2**” and “**CB2 CS2**”) is the same for each, with each circuit breaker having individual settings, and the functionality is similar to the first stages, but the second stages have an additional “**adaptive**” setting.

The synchronism check function in P446 relays can be set to provide appropriate synchronism check supervision of circuit breaker closing for either synchronous or asynchronous systems.

4.8.1 Synchronous Systems

Systems in which the frequency difference (“**slip frequency**”) between the voltages on either side of an open circuit breaker is practically zero are described as “**synchronous**”. Such systems are typically interconnected by other circuits in parallel with the open circuit breaker, which help to maintain synchronism even while the circuit breaker is open.

4.8.2 Asynchronous Systems/System Split

Systems which are electrically separated when a specific circuit breaker is open do not have parallel connections of sufficiently low impedance to maintain synchronism, and in the absence of any power flow between them the frequencies can drift apart, giving a significant slip frequency. Such systems are described as “**asynchronous**” or “**split**”, and are recognised by a measured slip frequency greater than the limiting slip frequency setting for synchronous systems.

4.8.3 Synchronism Check Functions Provided in the P446

Two independently settable synchronism check functions are provided for each circuit breaker controlled by the relay. “**CB1 CS1**” and/or “**CB1 CS2**” can be applied to supervise closing of circuit breaker CB1. “**CB2 CS1**” and/or “**CB2 CS2**” can be applied to supervise closing of circuit breaker CB2.

“**CB1 CS1**” and “**CB2 CS1**” are designed to be applied for synchronism check on synchronous systems, while “**CB1 CS2**” and “**CB2 CS2**” provide additional features which may be required for synchronism check on asynchronous systems. In situations where it is possible for the voltages on either side of a circuit breaker to be either synchronous or asynchronous depending on plant connections elsewhere on the system, both “**CBx CS1**” and “**CBx CS2**” can be enabled, to provide a permissive close signal if either set of permitted closing conditions is satisfied.

Each synchronism check function, as well as having the basic maximum phase angle difference and slip frequency settings, can also be set to inhibit circuit breaker closing if selected “**blocking**” conditions such as overvoltage, undervoltage or excessive voltage magnitude difference are detected. In addition, “**CB1 CS2**” and “**CB2 CS2**” each require the phase angle difference to be decreasing in magnitude to permit circuit breaker closing, and each has an optional “**Adaptive**” closing feature to issue the permissive close signal when the predicted phase angle difference immediately prior to the instant of circuit breaker main contacts closing (i.e. after CB Close time) is as close as practicable to zero.

Slip frequency can be defined as the difference between the voltage signals on either side of the circuit breaker, and represents a measure of the rate of change of phase between the two signals.

Having two system synchronism check stages available for each circuit breaker allows the circuit breaker closing to be enabled under different system conditions (for example, low slip/moderate phase angle, or moderate slip/small phase angle).

When the check synchronism criteria is satisfied, a DDB signal “**CBx CSy OK**” is set (x = 1 or 2, y = 1 or 2).

For “**CB1 CS1 OK**” DDB (883) to be set, the following conditions are necessary:

- Settings “**Sys Checks CB1**” and “**CB1 CS1 Status**” must **both** be Enabled;
- AND
- “**Live Line**” and “**Live Bus 1**” signals are both set;
- AND
- None of the selected “**CB1 CS1 Volt. Blk**” conditions (V<, V>, VDiff) are true;
- AND
- The measured phase angle magnitude is less than the “**CB1 CS1 Angle**” setting;
- AND
- If “**CB1 CS1 SlipCtrl**” setting is Enabled, the measured slip frequency between the line VT and Bus1 VT is less than the “**CB1 CS1 SlipFreq**” setting.

For signal “**CB1 CS2 OK**” DDB (884) to be set, the following conditions are necessary:

- Settings “**Sys Checks CB1**” and “**CB1 CS2 Status**” must both be Enabled;
- AND
- “**Live Line**” and “**Live Bus 1**” signals are both set;
- AND
- None of the selected “**CB1 CS1 Volt. Blk**” conditions (V<, V>, VDiff) are true;
- AND
- If “**CB1 CS2 SlipCtrl**” setting is Enabled, the measured slip frequency between the line VT and Bus1 VTs is less than the “**CB1 CS2 SlipFreq**” setting;
- AND
- The measured phase angle magnitude is decreasing;
- AND
- If the “**CB1 CS2 Adaptive**” setting is Disabled, the measured phase angle magnitude is less than the “**CB1 CS2 Angle**” setting;
- OR
- If the “**CB1 CS2 Adaptive**” setting is Enabled, AND if the predicted phase angle when CB1 closes (after “**CB1 Cl Time**” setting) is less than the “**CB1 CS2 Angle**” setting AND as close as possible to zero AND still decreasing in magnitude.

For "**CB2 CS1 OK**" DDB (1577) to be set, the following conditions are necessary:

- Settings "**Sys Checks CB2**" and "**CB2 CS1 Status**" must both be Enabled;
- AND
- "**Live Line**" and "**Live Bus 2**" signals are both set;
- AND
- None of the selected "**CB2 CS1 Volt. Blk**" conditions (V<, V>, VDiff) are true;
- AND
- The measured phase angle magnitude is less than the "**CB2 CS1 Angle**" setting;
- AND
- If "**CB2 CS1 SlipCtrl**" setting is Enabled the measured slip frequency between the line VT and Bus1 VT is less than the "**CB2 CS1 SlipFreq**" setting.

For signal "**CB2 CS2 OK**" DDB (1463) to be set, the following conditions are necessary:

- Settings "**Sys Checks CB2**" and "**CB2 CS2 Status**" must both be Enabled;
- AND
- "**Live Line**" and "**Live Bus 2**" signals are both set;
- AND
- None of the selected "**CB2 CS1 Volt. Blk**" conditions (V<, V>, VDiff) are true;
- AND
- If "**CB2 CS2 SlipCtrl**" setting is Enabled, the measured slip frequency between the line VT and Bus1 VTs is less than the "**CB2 CS2 SlipFreq**" setting;
- AND
- The measured phase angle magnitude is decreasing;
- AND
- If the "**CB2 CS2 Adaptive**" setting is Disabled, the measured phase angle magnitude is less than the "**CB2 CS2 Angle**" setting;
- OR
- If the "**CB2 CS2 Adaptive**" setting is Enabled, AND if the predicted phase angle when CB2 closes (after "**CB2 Cl Time**" setting) is less than the "**CB2 CS2 Angle**" setting AND as close as possible to zero AND still decreasing in magnitude.

5 P446 CB CONTROL AND AR FIGURES

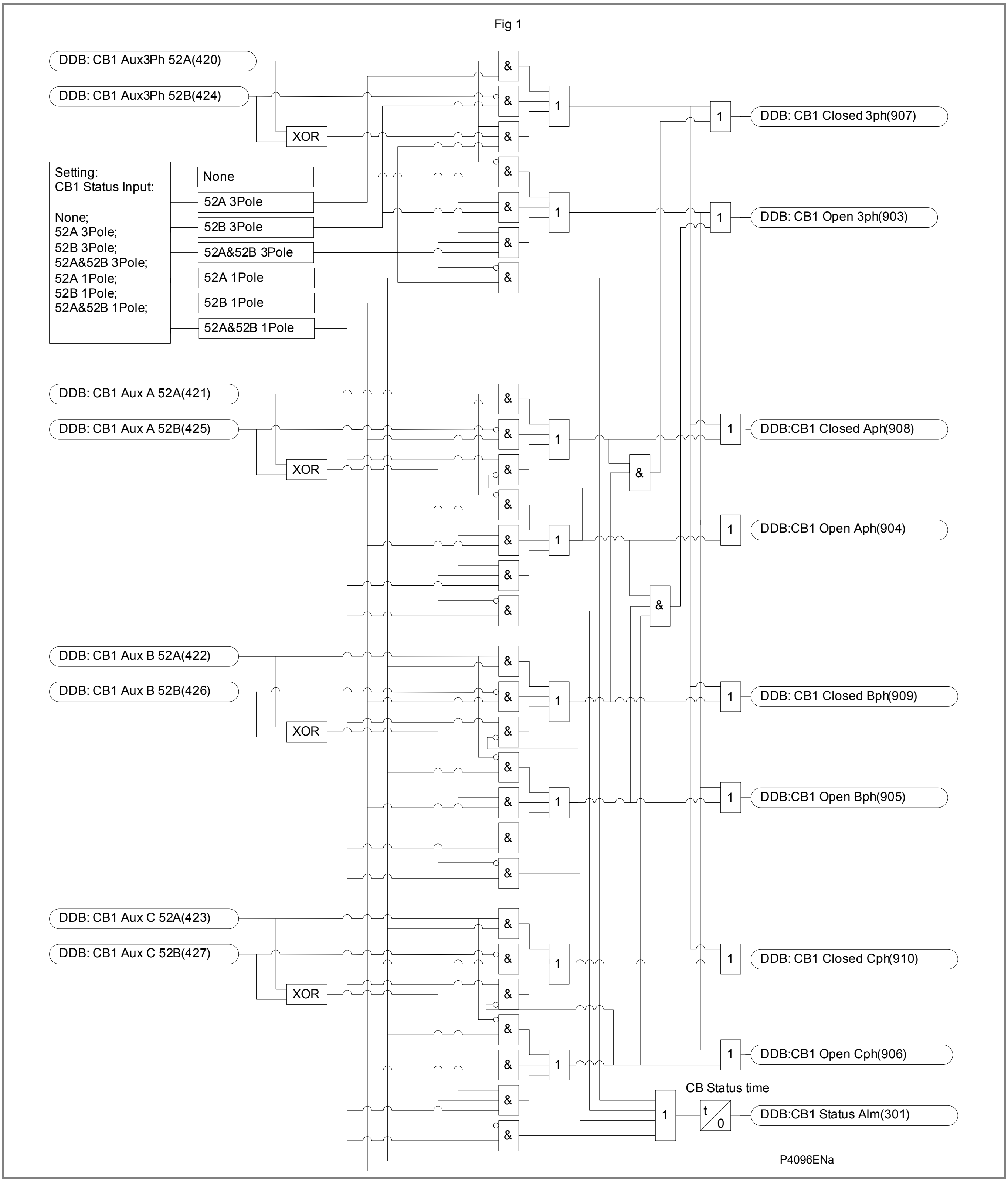


Fig 1
DDB: CB1 Aux3Ph 52A(420)
DDB: CB1 Aux3Ph 52B(424)
XOR
Setting:
CB1 Status Input:
None;
52A 3Pole;
52B 3Pole;
52A&52B 3Pole;
52A 1Pole;
52B 1Pole;
52A&52B 1Pole;
None
52A 3Pole
52B 3Pole
52A&52B 3Pole
52A 1Pole
52B 1Pole
52A&52B 1Pole
DDB: CB1 Closed 3ph(907)
DDB: CB1 Open 3ph(903)
DDB: CB1 Aux A 52A(421)
DDB: CB1 Aux A 52B(425)
DDB:CB1 Closed Aph(908)
DDB:CB1 Open Aph(904)
DDB: CB1 Aux B 52A(422)
DDB: CB1 Aux B 52B(426)
DDB: CB1 Closed Bph(909)
DDB:CB1 Open Bph(905)
DDB: CB1 Aux C 52A(423)
DDB: CB1 Aux C 52B(427)
DDB: CB1 Closed Cph(910)
DDB:CB1 Open Cph(906)
CB Status time
t
0
DDB:CB1 Status Alm(301)
P4096ENa

Figure AR 120 - Circuit breaker 1 - state monitor

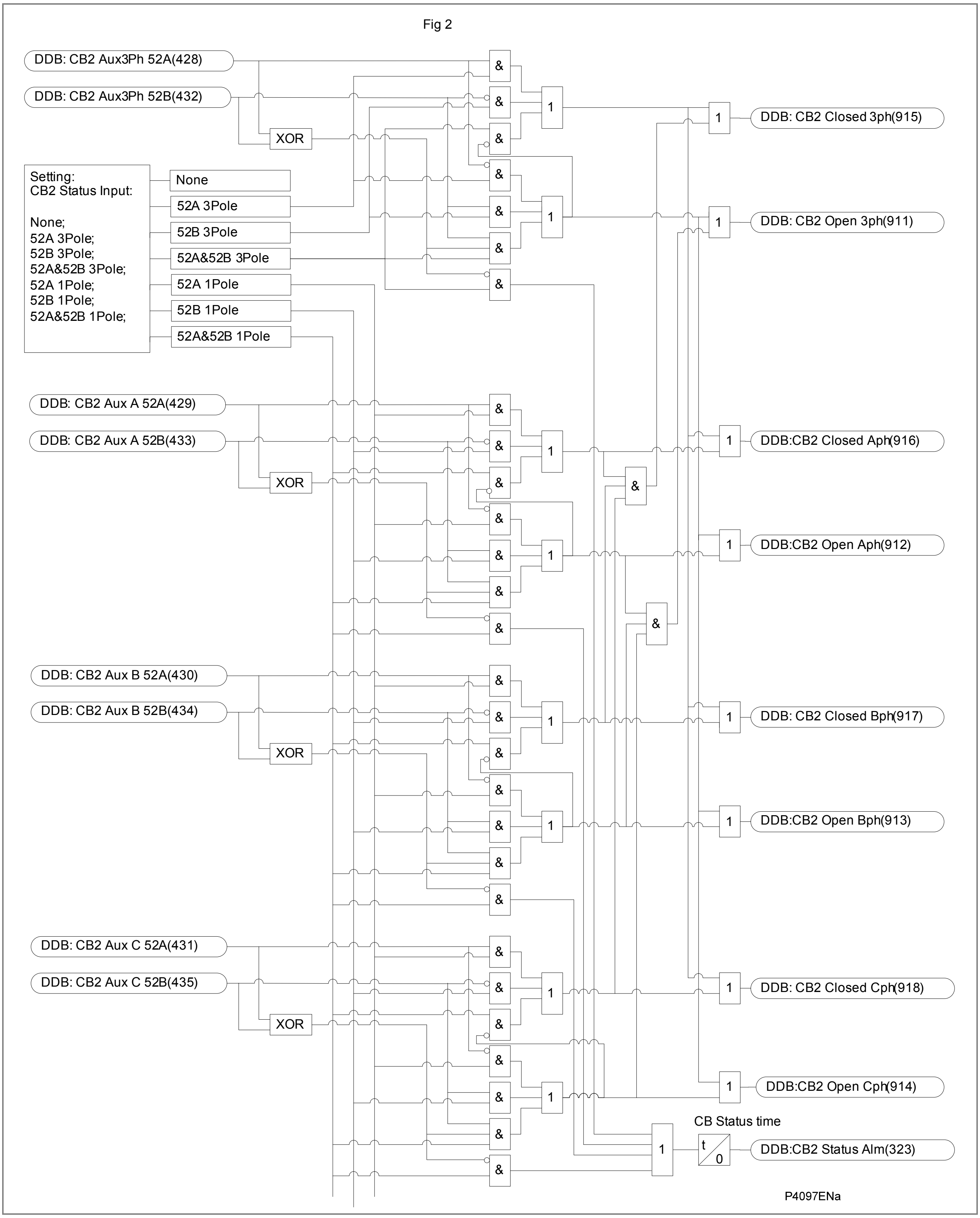


Fig 2
DDB: CB2 Aux3Ph 52A(428)
DDB: CB2 Aux3Ph 52B(432)
XOR
Setting:
CB2 Status Input:
None;
52A 3Pole;
52B 3Pole;
52A&52B 3Pole;
52A 1Pole;
52B 1Pole;
52A&52B 1Pole;
None
52A 3Pole
52B 3Pole
52A&52B 3Pole
52A 1Pole
52B 1Pole
52A&52B 1Pole
DDB: CB2 Closed 3ph(915)
DDB: CB2 Open 3ph(911)
DDB: CB2 Aux A 52A(429)
DDB: CB2 Aux A 52B(433)
XOR
DDB:CB2 Closed Aph(916)
DDB:CB2 Open Aph(912)
DDB: CB2 Aux B 52A(430)
DDB: CB2 Aux B 52B(434)
XOR
DDB: CB2 Closed Bph(917)
DDB:CB2 Open Bph(913)
DDB: CB2 Aux C 52A(431)
DDB: CB2 Aux C 52B(435)
XOR
DDB: CB2 Closed Cph(918)
DDB:CB2 Open Cph(914)
CB Status time
t
0
DDB:CB2 Status Alm(323)
&
1
P4097ENa

Figure AR 121 - Circuit breaker 2 - state monitor

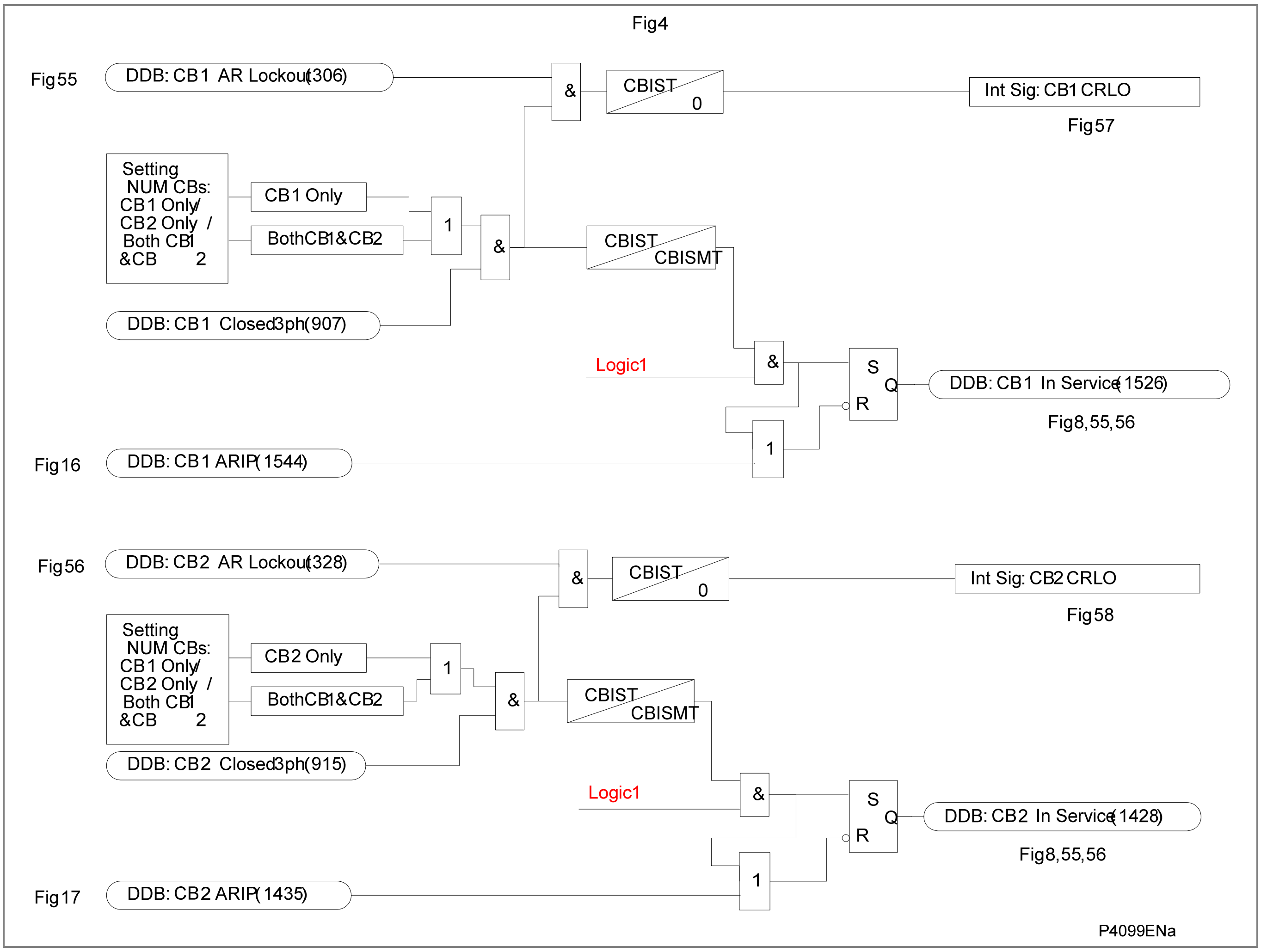


Fig4
Fig55
DDB: CB1 AR Lockout(306)
&
CBIST
0
Int Sig: CB1 CRLO
Fig57
Setting
NUM CBs:
CB1 Only/
CB2 Only /
Both CB1
&CB 2
CB1 Only
BothCB1&CB2
1
&
CBIST
CBISMT
DDB: CB1 Closed3ph(907)
Logic1
&
S
Q
R
DDB: CB1 In Service(1526)
Fig8,55,56
1
Fig16
DDB: CB1 ARIP(1544)
Fig56
DDB: CB2 AR Lockout(328)
&
CBIST
0
Int Sig: CB2 CRLO
Fig58
Setting
NUM CBs:
CB1 Only/
CB2 Only /
Both CB1
&CB 2
CB2 Only
BothCB1&CB2
1
&
CBIST
CBISMT
DDB: CB2 Closed3ph(915)
Logic1
&
S
Q
R
DDB: CB2 In Service(1428)
Fig8,55,56
1
Fig17
DDB: CB2 ARIP(1435)
P4099ENa

Figure AR 122 - Circuit breaker in service

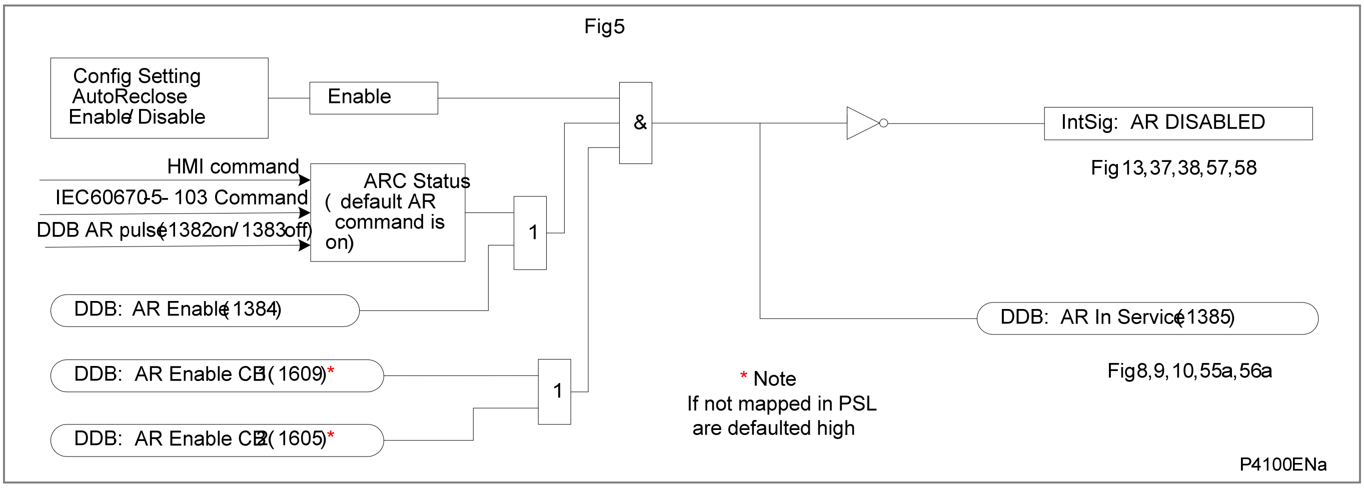


Fig5
Config Setting
AutoReclose
Enable/ Disable
Enable
&
IntSig: AR DISABLED
Fig13,37,38,57,58
HMI command
IEC60670-5-103 Command
DDB AR pulse(1382on/1383off)
ARC Status
(default AR
command is
on)
1
DDB: AR Enable(1384)
DDB: AR In Service(1385)
Fig8,9,10,55a,56a
DDB: AR Enable CB1(1609)*
1
DDB: AR Enable CB2(1605)*
* Note
If not mapped in PSL
are defaulted high
P4100ENa

Figure AR 123 - Auto-reclose enable

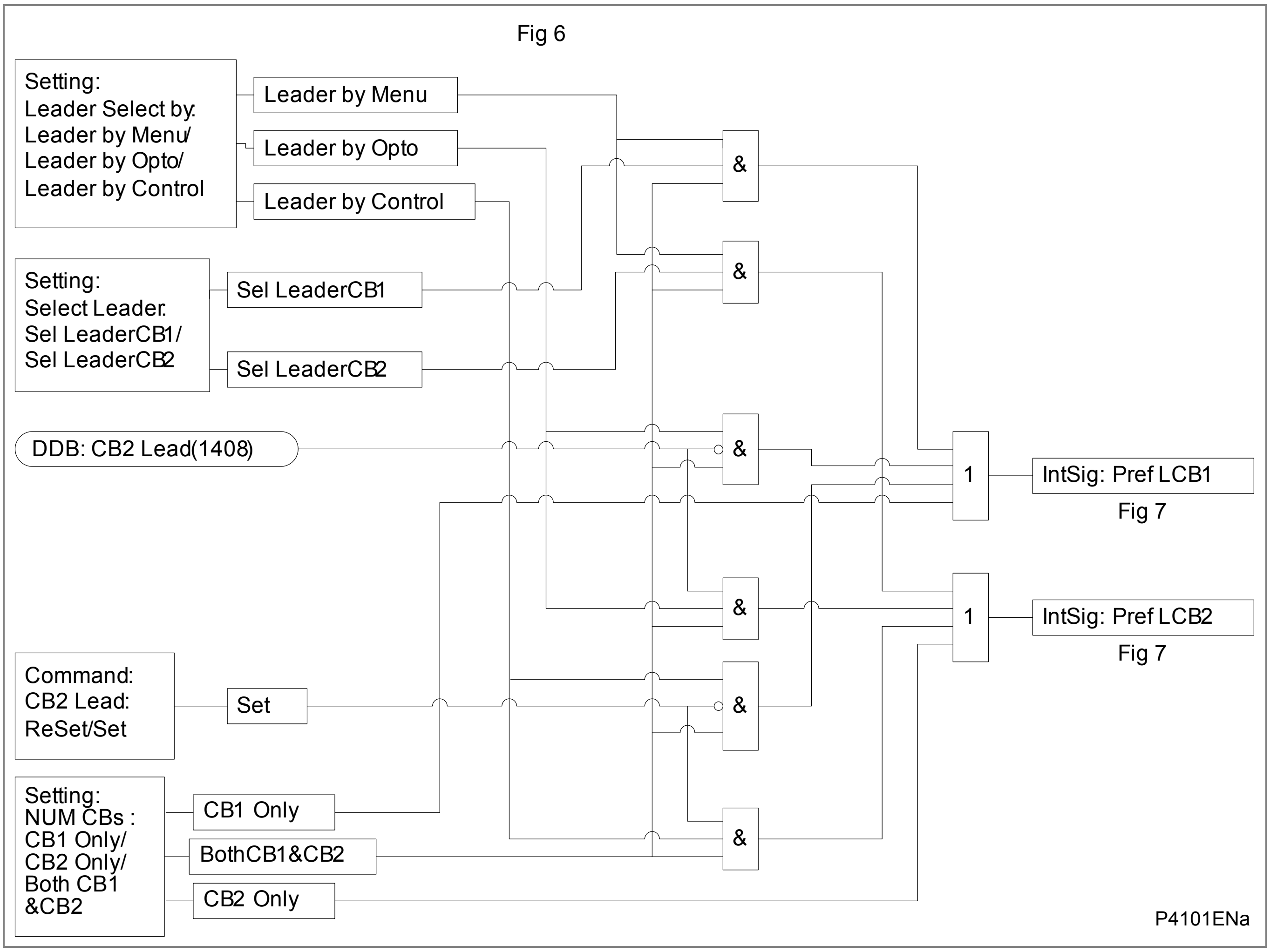


Fig 6
Setting:
Leader Select by:
Leader by Menu/
Leader by Opto/
Leader by Control
Leader by Menu
Leader by Opto
Leader by Control
Setting:
Select Leader:
Sel LeaderCB1/
Sel LeaderCB2
Sel LeaderCB1
Sel LeaderCB2
DDB: CB2 Lead(1408)
Command:
CB2 Lead:
ReSet/Set
Set
Setting:
NUM CBs :
CB1 Only/
CB2 Only/
Both CB1
&CB2
CB1 Only
BothCB1&CB2
CB2 Only
&
&
&
&
&
&
1
1
IntSig: Pref LCB1
Fig 7
IntSig: Pref LCB2
Fig 7
P4101ENa

Figure AR 124 - Lead & follower circuit breaker selection

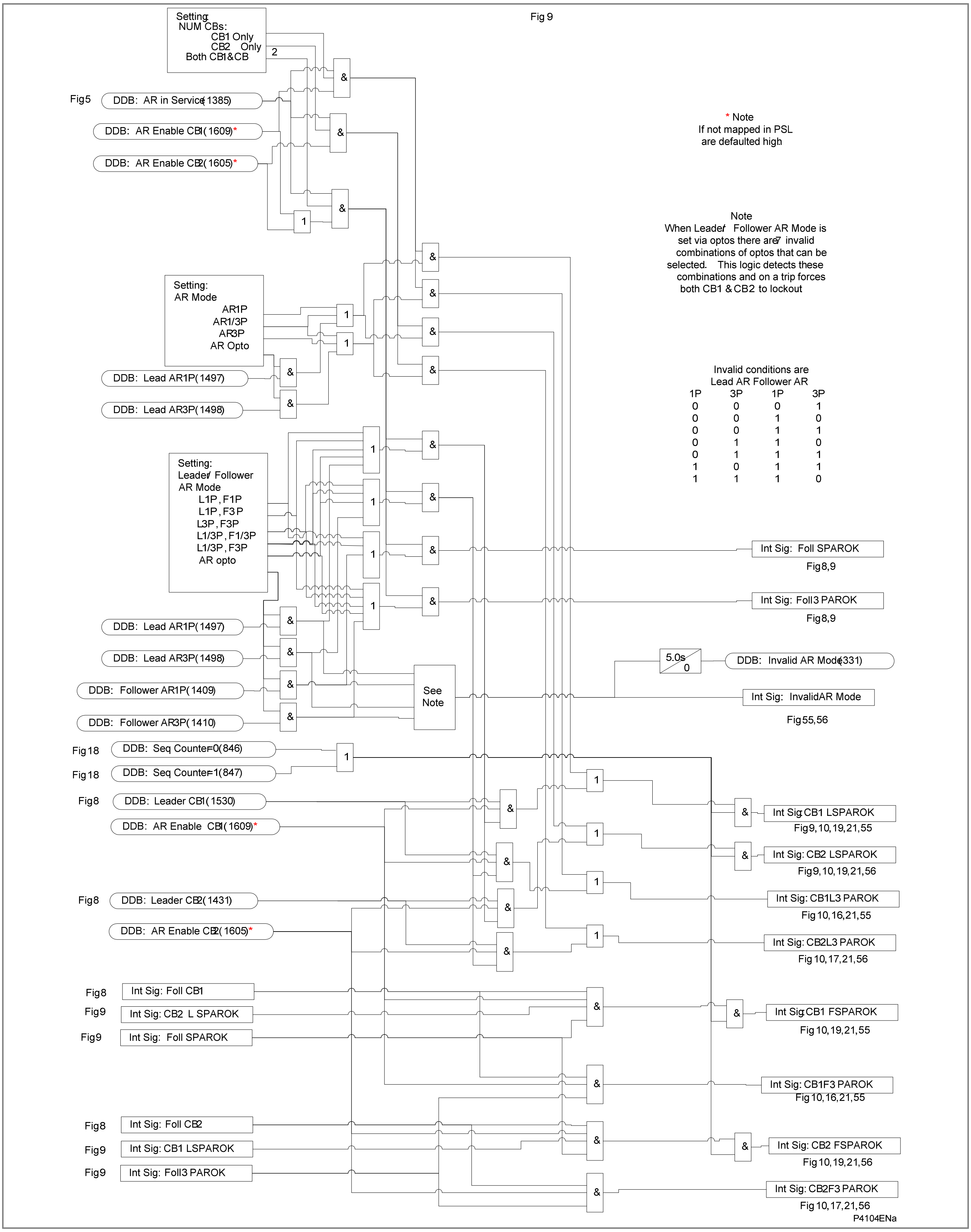

Setting: NUM CBs:
CB1 Only
CB2 Only
Both CB1&CB
2
Fig 9
Fig5
DDB: AR in Service (1385)
DDB: AR Enable CB1 (1609)*
DDB: AR Enable CB2 (1605)*
* Note
If not mapped in PSL
are defaulted high
Note
When Leader / Follower AR Mode is
set via optos there are 7 invalid
combinations of optos that can be
selected. This logic detects these
combinations and on a trip forces
both CB1 & CB2 to lockout
Setting:
AR Mode
AR1P
AR1/3P
AR3P
AR Opto
DDB: Lead AR1P (1497)
DDB: Lead AR3P (1498)
Invalid conditions are
Lead AR Follower AR
1P 3P 1P 3P
0 0 0 1
0 0 1 0
0 0 1 1
0 1 1 0
0 1 1 1
1 0 1 1
1 1 1 0
Setting:
Leader / Follower
AR Mode
L1P, F1P
L1P, F3P
L3P, F3P
L1/3P, F1/3P
L1/3P, F3P
AR opto
Int Sig: Foll SPAROK
Fig8,9
Int Sig: Foll3 PAROK
Fig8,9
DDB: Lead AR1P (1497)
DDB: Lead AR3P (1498)
DDB: Follower AR1P (1409)
DDB: Follower AR3P (1410)
See Note
5.0s
0
DDB: Invalid AR Mode (331)
Int Sig: InvalidAR Mode
Fig55,56
Fig18
DDB: Seq Counter=0 (846)
Fig18
DDB: Seq Counter=1 (847)
Fig8
DDB: Leader CB1 (1530)
DDB: AR Enable CB1 (1609)*
Int Sig: CB1 LSPAROK
Fig9,10,19,21,55
Int Sig: CB2 LSPAROK
Fig9,10,19,21,56
Fig8
DDB: Leader CB2 (1431)
Int Sig: CB1L3 PAROK
Fig10,16,21,55
DDB: AR Enable CB2 (1605)*
Int Sig: CB2L3 PAROK
Fig10,17,21,56
Fig8
Int Sig: Foll CB1
Fig9
Int Sig: CB2 L SPAROK
Fig9
Int Sig: Foll SPAROK
Int Sig: CB1 FSPAROK
Fig10,19,21,55
Int Sig: CB1F3 PAROK
Fig10,16,21,55
Fig8
Int Sig: Foll CB2
Fig9
Int Sig: CB1 LSPAROK
Fig9
Int Sig: Foll3 PAROK
Int Sig: CB2 FSPAROK
Fig10,19,21,56
Int Sig: CB2F3 PAROK
Fig10,17,21,56
P4104ENa

Figure AR 125 - Lead & follower circuit breaker auto-reclose mode selection

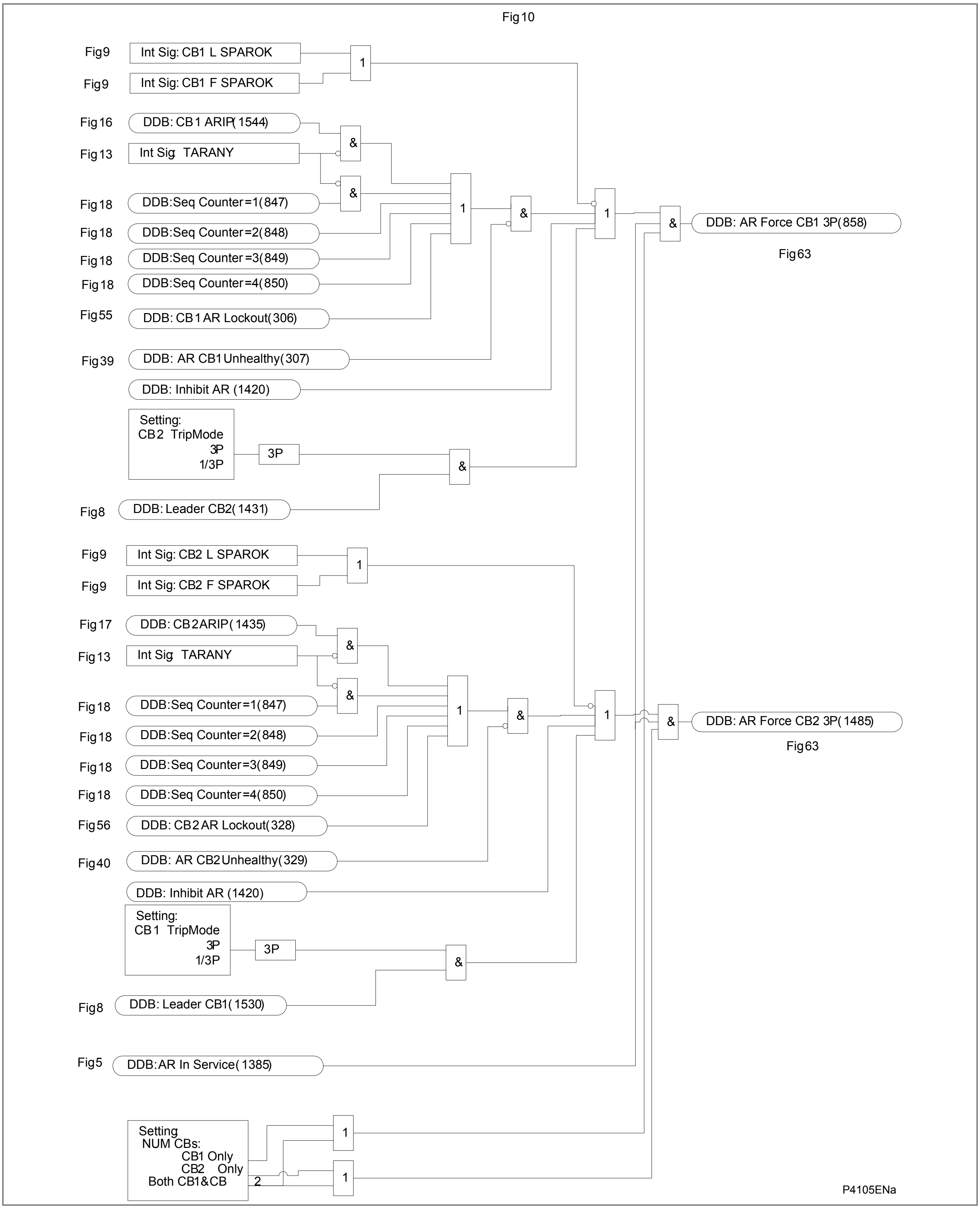


Fig10
Fig9
Int Sig: CB1 L SPAROK
Fig9
Int Sig: CB1 F SPAROK
Fig16
DDB: CB1 ARIP(1544)
Fig13
Int Sig TARANY
Fig18
DDB:Seq Counter=1(847)
Fig18
DDB:Seq Counter=2(848)
Fig18
DDB:Seq Counter=3(849)
Fig18
DDB:Seq Counter=4(850)
Fig55
DDB: CB1 AR Lockout(306)
Fig39
DDB: AR CB1 Unhealthy(307)
DDB: Inhibit AR (1420)
Setting:
CB2 TripMode
3P
1/3P
3P
Fig8
DDB: Leader CB2(1431)
DDB: AR Force CB1 3P(858)
Fig63
Fig9
Int Sig: CB2 L SPAROK
Fig9
Int Sig: CB2 F SPAROK
Fig17
DDB: CB2 ARIP(1435)
Fig13
Int Sig TARANY
Fig18
DDB:Seq Counter=1(847)
Fig18
DDB:Seq Counter=2(848)
Fig18
DDB:Seq Counter=3(849)
Fig18
DDB:Seq Counter=4(850)
Fig56
DDB: CB2 AR Lockout(328)
Fig40
DDB: AR CB2 Unhealthy(329)
DDB: Inhibit AR (1420)
Setting:
CB1 TripMode
3P
1/3P
3P
Fig8
DDB: Leader CB1(1530)
DDB: AR Force CB2 3P(1485)
Fig63
Fig5
DDB:AR In Service(1385)
Setting
NUM CBs:
CB1 Only
CB2 Only
Both CB1&CB
2
1
&
P4105ENa

Figure AR 126 - Force three phase trip

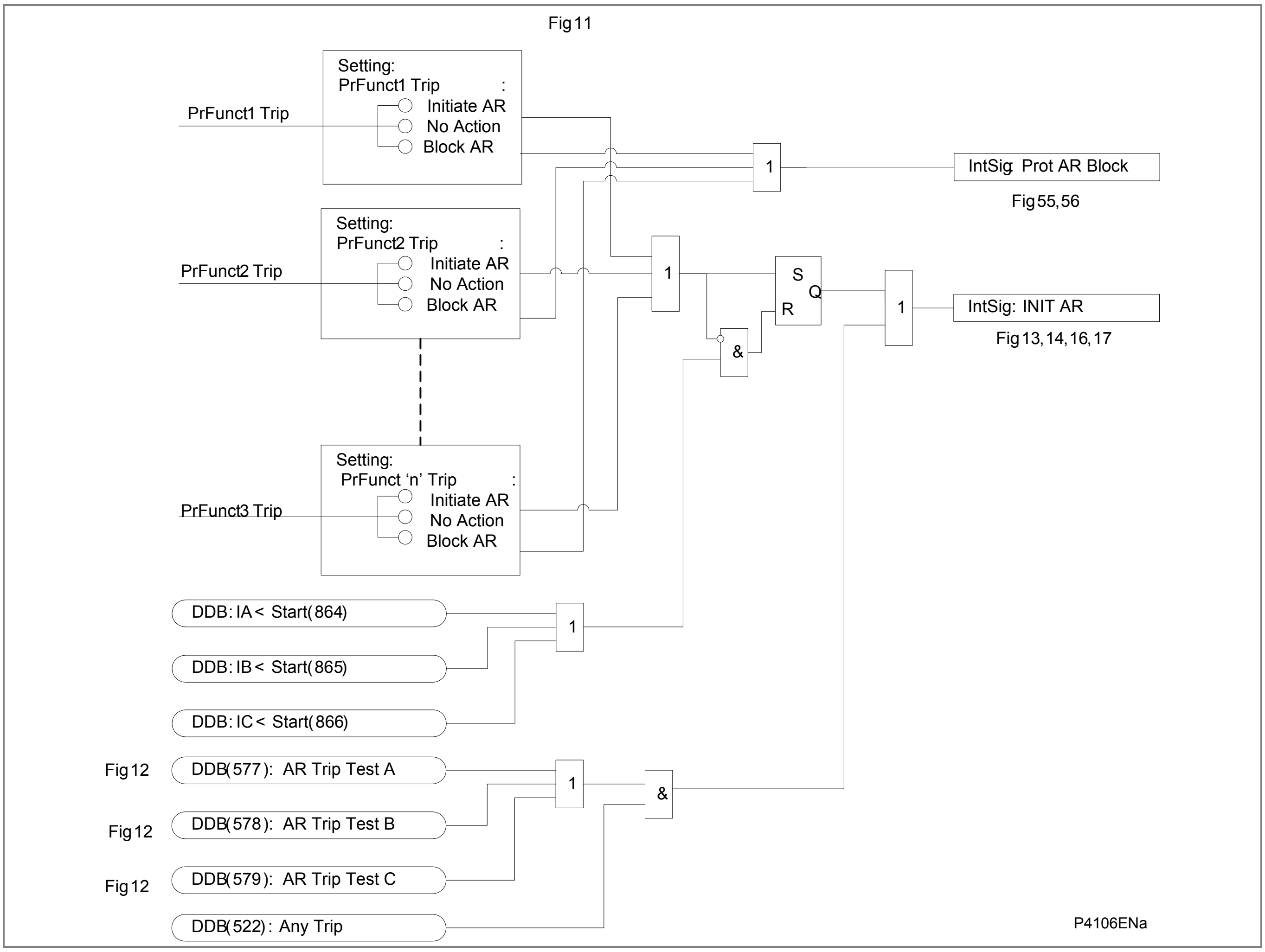


Fig 11
Setting:
PrFunct1 Trip :
Initiate AR
No Action
Block AR
PrFunct1 Trip
Setting:
PrFunct2 Trip :
Initiate AR
No Action
Block AR
PrFunct2 Trip
Setting:
PrFunct 'n' Trip :
Initiate AR
No Action
Block AR
PrFunct3 Trip
1
IntSig: Prot AR Block
Fig 55, 56
1
S
Q
R
&
1
IntSig: INIT AR
Fig 13, 14, 16, 17
DDB: IA< Start (864)
DDB: IB< Start (865)
DDB: IC< Start (866)
1
Fig 12
DDB (577): AR Trip Test A
Fig 12
DDB (578): AR Trip Test B
Fig 12
DDB (579): AR Trip Test C
DDB (522): Any Trip
1
&
P4106ENa

Figure AR 127 - Auto-reclose initiation

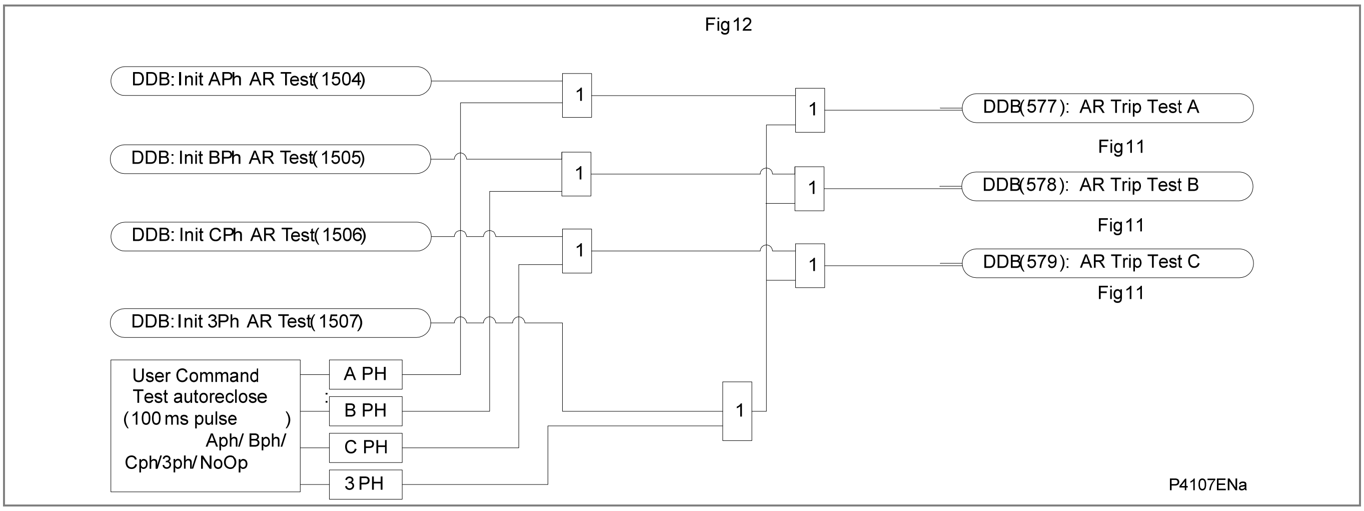


Fig 12
DDB: Init APh AR Test (1504)
DDB: Init BPh AR Test (1505)
DDB: Init CPh AR Test (1506)
DDB: Init 3Ph AR Test (1507)
1
1
1
1
1
1
1
User Command
Test autoreclose :
(100 ms pulse)
Aph/ Bph/
Cph/3ph/ NoOp
A PH
B PH
C PH
3 PH
DDB (577): AR Trip Test A
Fig 11
DDB (578): AR Trip Test B
Fig 11
DDB (579): AR Trip Test C
Fig 11
P4107ENa

Figure AR 128 - Test trip &AR initiation

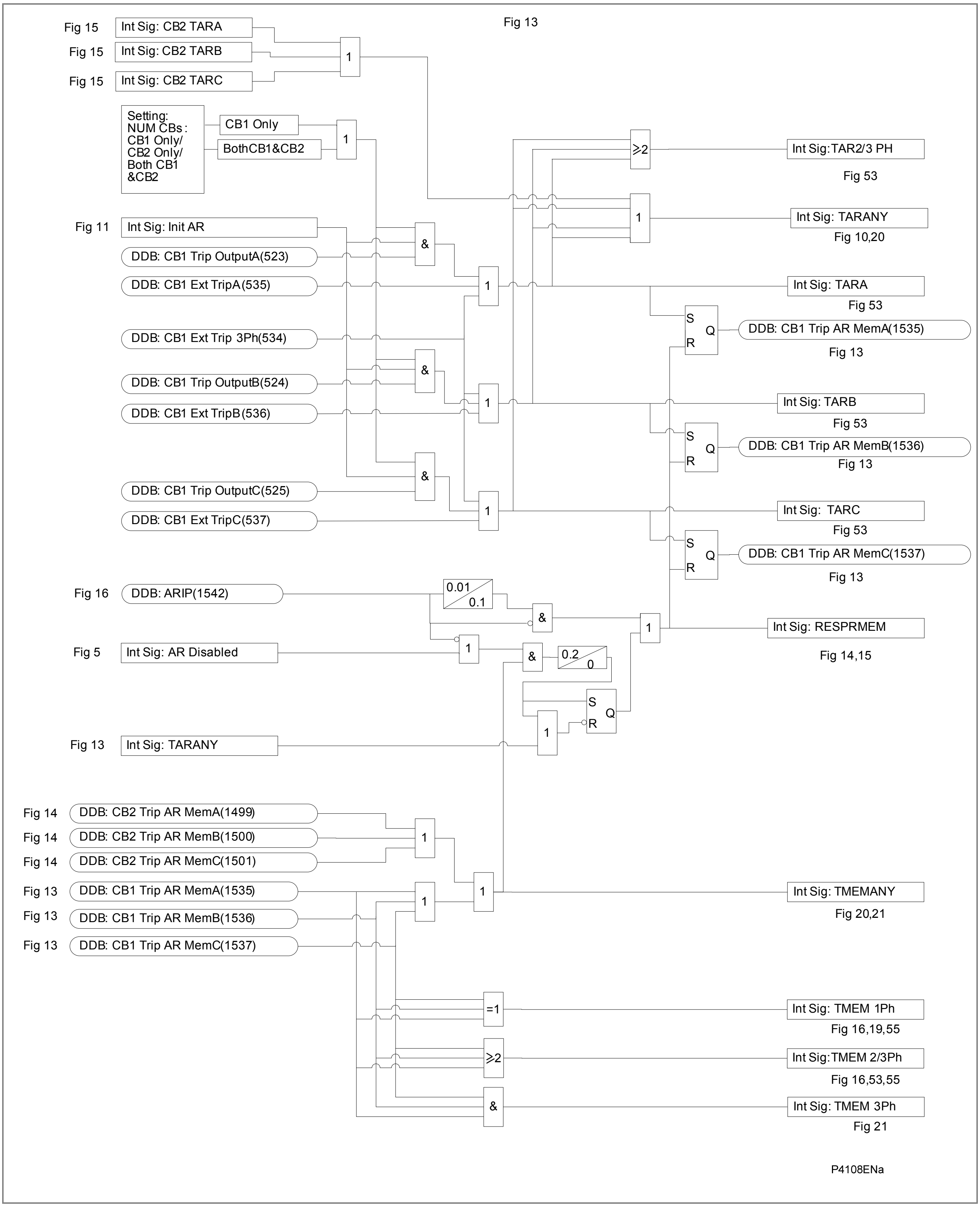


Fig 15
Int Sig: CB2 TARA
Fig 15
Int Sig: CB2 TARB
Fig 15
Int Sig: CB2 TARC
1
Fig 13
Setting: NUM CBs : CB1 Only/ CB2 Only/ Both CB1 &CB2
CB1 Only
BothCB1&CB2
1
≥2
Int Sig:TAR2/3 PH
Fig 53
1
Int Sig: TARANY
Fig 10,20
Fig 11
Int Sig: Init AR
&
DDB: CB1 Trip OutputA(523)
DDB: CB1 Ext TripA(535)
1
Int Sig: TARA
Fig 53
S
Q
R
DDB: CB1 Trip AR MemA(1535)
Fig 13
DDB: CB1 Ext Trip 3Ph(534)
&
DDB: CB1 Trip OutputB(524)
DDB: CB1 Ext TripB(536)
1
Int Sig: TARB
Fig 53
S
Q
R
DDB: CB1 Trip AR MemB(1536)
Fig 13
&
DDB: CB1 Trip OutputC(525)
DDB: CB1 Ext TripC(537)
1
Int Sig: TARC
Fig 53
S
Q
R
DDB: CB1 Trip AR MemC(1537)
Fig 13
Fig 16
DDB: ARIP(1542)
0.01
0.1
&
1
Int Sig: RESPRMEM
Fig 14,15
Fig 5
Int Sig: AR Disabled
1
&
0.2
0
S
Q
R
1
Fig 13
Int Sig: TARANY
Fig 14
DDB: CB2 Trip AR MemA(1499)
Fig 14
DDB: CB2 Trip AR MemB(1500)
Fig 14
DDB: CB2 Trip AR MemC(1501)
1
Fig 13
DDB: CB1 Trip AR MemA(1535)
Fig 13
DDB: CB1 Trip AR MemB(1536)
Fig 13
DDB: CB1 Trip AR MemC(1537)
1
1
Int Sig: TMEMANY
Fig 20,21
=1
Int Sig: TMEM 1Ph
Fig 16,19,55
≥2
Int Sig:TMEM 2/3Ph
Fig 16,53,55
&
Int Sig: TMEM 3Ph
Fig 21
P4108ENa

Figure AR 129 - CB1 1 pole/3 pole trip & AR initiation

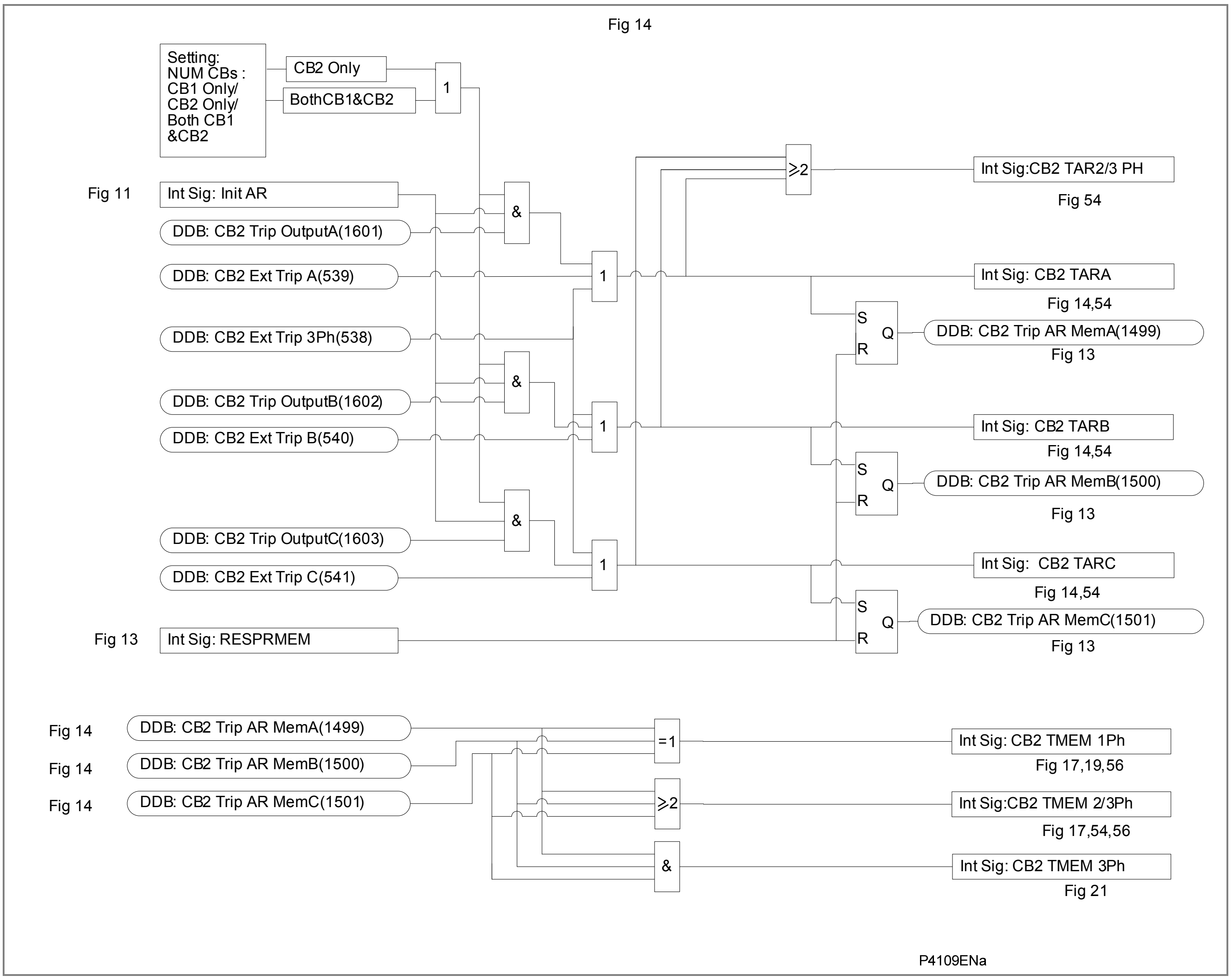


Fig 14
Setting: NUM CBs : CB1 Only/ CB2 Only/ Both CB1 &CB2
CB2 Only
BothCB1&CB2
1
≥2
Int Sig:CB2 TAR2/3 PH
Fig 54
Fig 11
Int Sig: Init AR
&
DDB: CB2 Trip OutputA(1601)
DDB: CB2 Ext Trip A(539)
1
Int Sig: CB2 TARA
Fig 14,54
S
Q
R
DDB: CB2 Ext Trip 3Ph(538)
DDB: CB2 Trip AR MemA(1499)
Fig 13
&
DDB: CB2 Trip OutputB(1602)
1
Int Sig: CB2 TARB
DDB: CB2 Ext Trip B(540)
Fig 14,54
S
Q
R
DDB: CB2 Trip AR MemB(1500)
Fig 13
&
DDB: CB2 Trip OutputC(1603)
1
Int Sig: CB2 TARC
DDB: CB2 Ext Trip C(541)
Fig 14,54
S
Q
R
DDB: CB2 Trip AR MemC(1501)
Fig 13
Int Sig: RESPRMEM
Fig 13
Fig 14
DDB: CB2 Trip AR MemA(1499)
=1
Int Sig: CB2 TMEM 1Ph
Fig 14
DDB: CB2 Trip AR MemB(1500)
Fig 17,19,56
Fig 14
DDB: CB2 Trip AR MemC(1501)
≥2
Int Sig:CB2 TMEM 2/3Ph
Fig 17,54,56
&
Int Sig: CB2 TMEM 3Ph
Fig 21
P4109ENa

Figure AR 130 - CB2 1 pole/3 pole trip & AR initiation

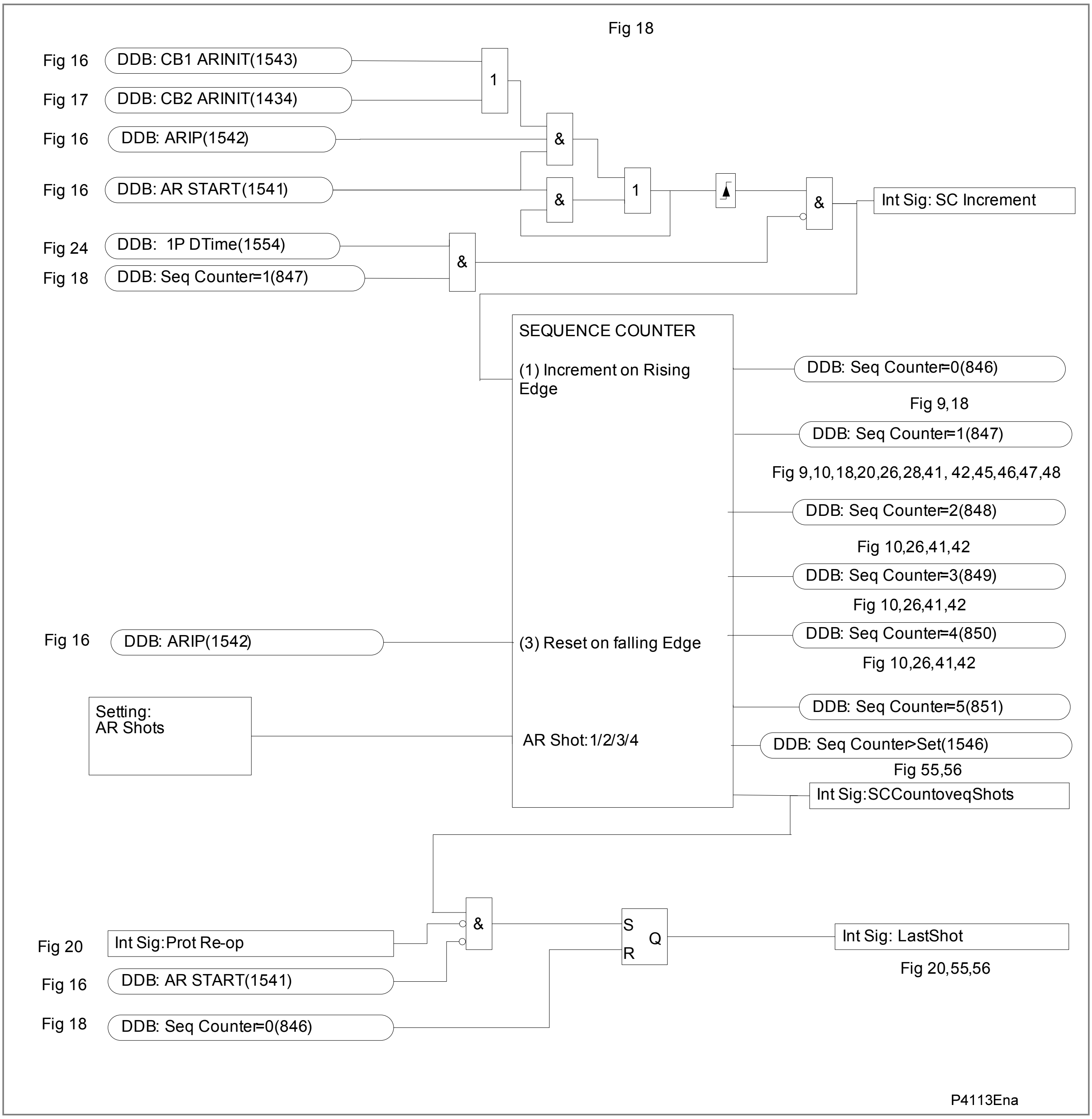


Fig 18
Fig 16
DDB: CB1 ARINIT(1543)
Fig 17
DDB: CB2 ARINIT(1434)
Fig 16
DDB: ARIP(1542)
Fig 16
DDB: AR START(1541)
Fig 24
DDB: 1P DTime(1554)
Fig 18
DDB: Seq Counter=1(847)
1
&
&
1
&
&
Int Sig: SC Increment
SEQUENCE COUNTER
(1) Increment on Rising Edge
(3) Reset on falling Edge
AR Shot:1/2/3/4
DDB: Seq Counter=0(846)
Fig 9,18
DDB: Seq Counter=1(847)
Fig 9,10,18,20,26,28,41, 42,45,46,47,48
DDB: Seq Counter=2(848)
Fig 10,26,41,42
DDB: Seq Counter=3(849)
Fig 10,26,41,42
DDB: Seq Counter=4(850)
Fig 10,26,41,42
DDB: Seq Counter=5(851)
DDB: Seq Counter>Set(1546)
Fig 55,56
Int Sig:SCCountoveqShots
Fig 16
DDB: ARIP(1542)
Setting:
AR Shots
Fig 20
Int Sig:Prot Re-op
Fig 16
DDB: AR START(1541)
Fig 18
DDB: Seq Counter=0(846)
&
S
R
Q
Int Sig: LastShot
Fig 20,55,56
P4113Ena

Figure AR 131 - Sequence counter

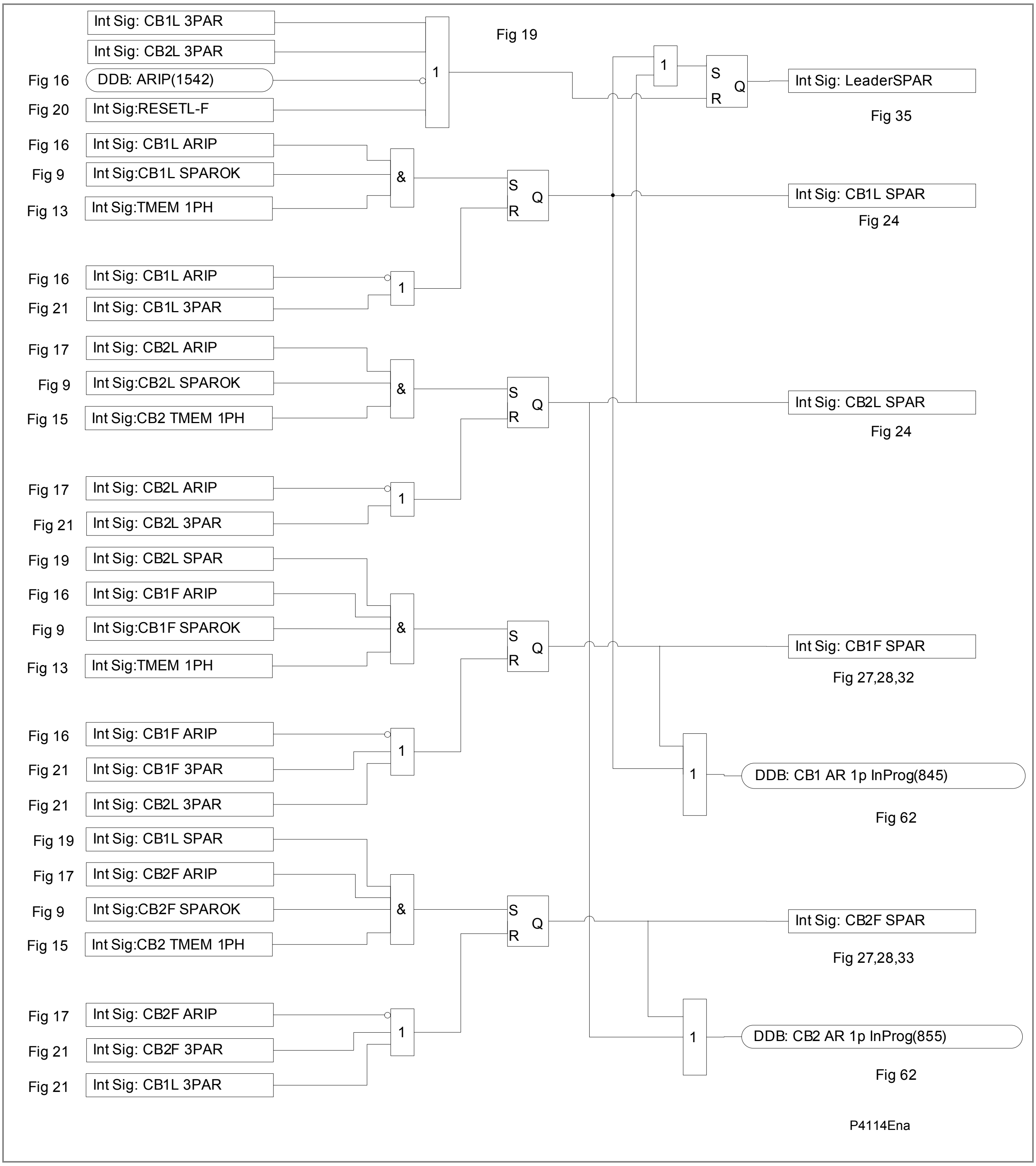

Int Sig: CB1L 3PAR
Int Sig: CB2L 3PAR
Fig 16
DDB: ARIP(1542)
Fig 20
Int Sig:RESETL-F
1
Fig 19
1
S
R
Q
Int Sig: LeaderSPAR
Fig 35
Fig 16
Int Sig: CB1L ARIP
Fig 9
Int Sig:CB1L SPAROK
Fig 13
Int Sig:TMEM 1PH
&
S
Q
R
Int Sig: CB1L SPAR
Fig 24
Fig 16
Int Sig: CB1L ARIP
Fig 21
Int Sig: CB1L 3PAR
1
Fig 17
Int Sig: CB2L ARIP
Fig 9
Int Sig:CB2L SPAROK
Fig 15
Int Sig:CB2 TMEM 1PH
&
S
Q
R
Int Sig: CB2L SPAR
Fig 24
Fig 17
Int Sig: CB2L ARIP
Fig 21
Int Sig: CB2L 3PAR
1
Fig 19
Int Sig: CB2L SPAR
Fig 16
Int Sig: CB1F ARIP
Fig 9
Int Sig:CB1F SPAROK
Fig 13
Int Sig:TMEM 1PH
&
S
Q
R
Int Sig: CB1F SPAR
Fig 27,28,32
Fig 16
Int Sig: CB1F ARIP
Fig 21
Int Sig: CB1F 3PAR
Fig 21
Int Sig: CB2L 3PAR
1
1
DDB: CB1 AR 1p InProg(845)
Fig 62
Fig 19
Int Sig: CB1L SPAR
Fig 17
Int Sig: CB2F ARIP
Fig 9
Int Sig:CB2F SPAROK
Fig 15
Int Sig:CB2 TMEM 1PH
&
S
Q
R
Int Sig: CB2F SPAR
Fig 27,28,33
Fig 17
Int Sig: CB2F ARIP
Fig 21
Int Sig: CB2F 3PAR
Fig 21
Int Sig: CB1L 3PAR
1
1
DDB: CB2 AR 1p InProg(855)
Fig 62
P4114Ena

Figure AR 132 - Single phase auto-reclose cycle selection

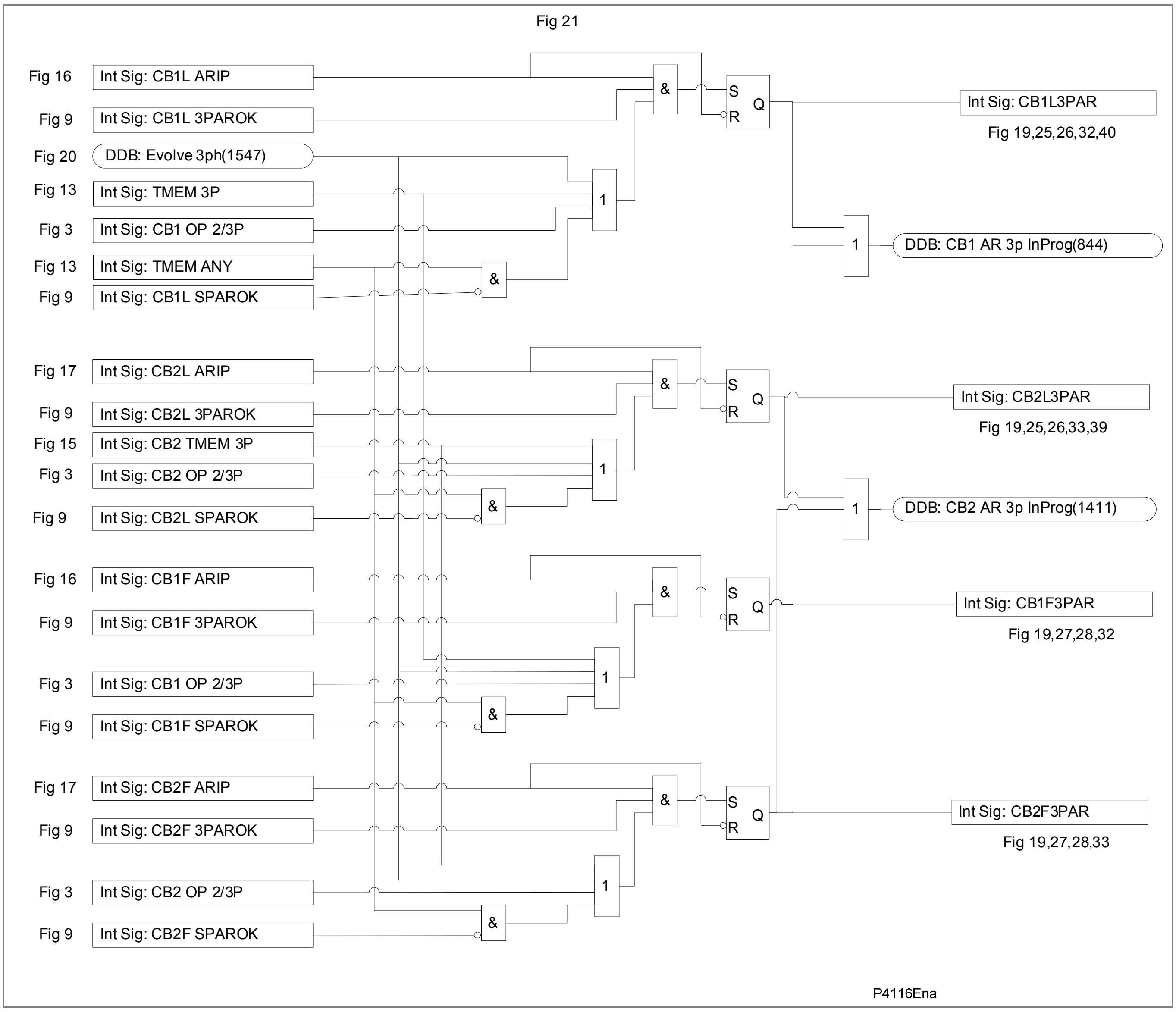


Fig 21
Fig 16
Int Sig: CB1L ARIP
Fig 9
Int Sig: CB1L 3PAROK
Fig 20
DDB: Evolve 3ph(1547)
Fig 13
Int Sig: TMEM 3P
Fig 3
Int Sig: CB1 OP 2/3P
Fig 13
Int Sig: TMEM ANY
Fig 9
Int Sig: CB1L SPAROK
Fig 17
Int Sig: CB2L ARIP
Fig 9
Int Sig: CB2L 3PAROK
Fig 15
Int Sig: CB2 TMEM 3P
Fig 3
Int Sig: CB2 OP 2/3P
Fig 9
Int Sig: CB2L SPAROK
Fig 16
Int Sig: CB1F ARIP
Fig 9
Int Sig: CB1F 3PAROK
Fig 3
Int Sig: CB1 OP 2/3P
Fig 9
Int Sig: CB1F SPAROK
Fig 17
Int Sig: CB2F ARIP
Fig 9
Int Sig: CB2F 3PAROK
Fig 3
Int Sig: CB2 OP 2/3P
Fig 9
Int Sig: CB2F SPAROK
&
1
S
R
Q
Int Sig: CB1L3PAR
Fig 19,25,26,32,40
DDB: CB1 AR 3p InProg(844)
Int Sig: CB2L3PAR
Fig 19,25,26,33,39
DDB: CB2 AR 3p InProg(1411)
Int Sig: CB1F3PAR
Fig 19,27,28,32
Int Sig: CB2F3PAR
Fig 19,27,28,33
P4116Ena

Figure AR 133 - Three phase auto-reclose cycle selection

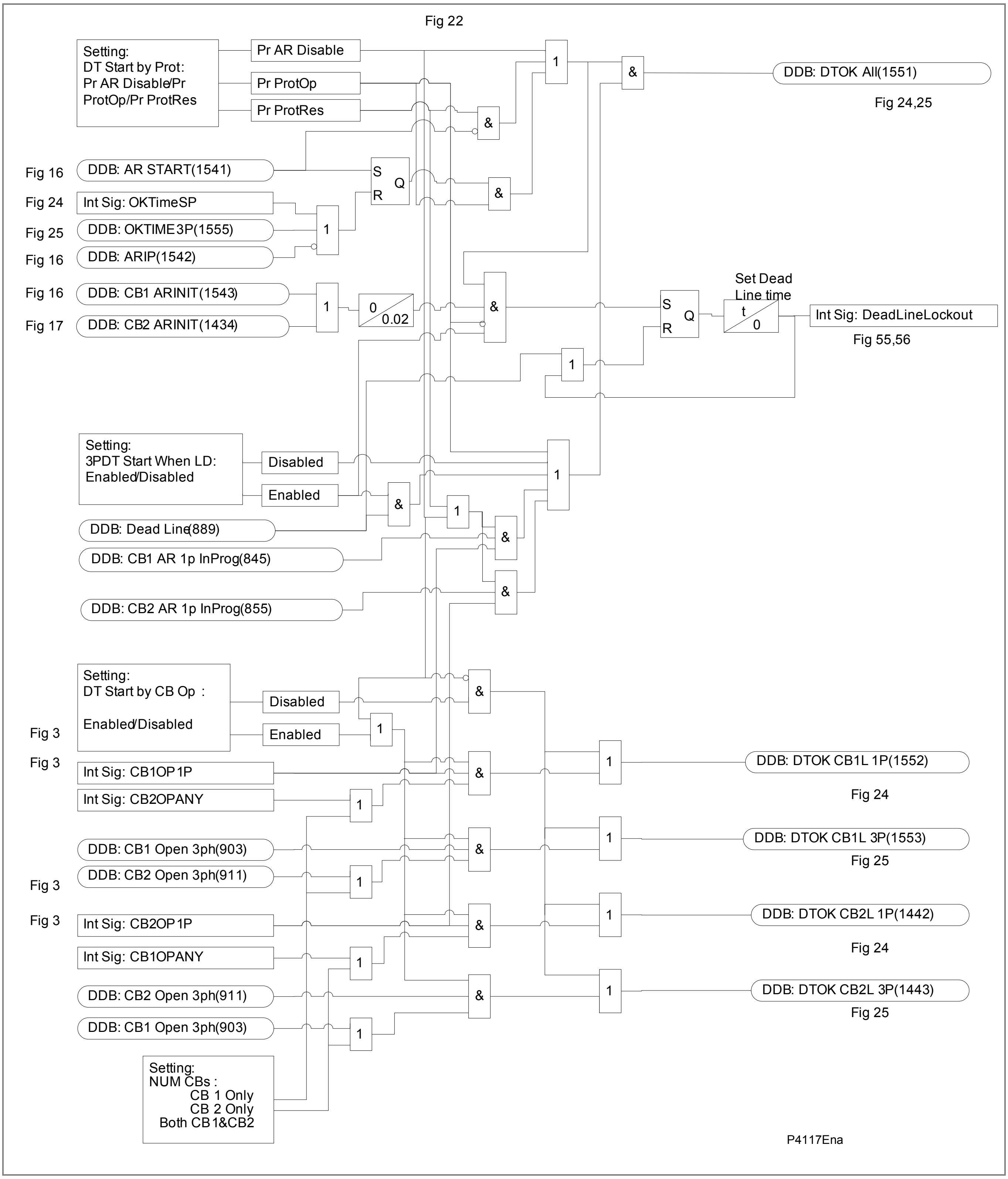


Fig 22
Setting:
DT Start by Prot:
Pr AR Disable/Pr
ProtOp/Pr ProtRes
Pr AR Disable
Pr ProtOp
Pr ProtRes
DDB: DTOK All(1551)
Fig 24,25
Fig 16
DDB: AR START(1541)
Fig 24
Int Sig: OKTimeSP
Fig 25
DDB: OKTIME3P(1555)
Fig 16
DDB: ARIP(1542)
Fig 16
DDB: CB1 ARINIT(1543)
Fig 17
DDB: CB2 ARINIT(1434)
S
Q
R
0
0.02
Set Dead
Line time
t
0
Int Sig: DeadLineLockout
Fig 55,56
Setting:
3PDT Start When LD:
Enabled/Disabled
Disabled
Enabled
DDB: Dead Line(889)
DDB: CB1 AR 1p InProg(845)
DDB: CB2 AR 1p InProg(855)
Setting:
DT Start by CB Op :
Enabled/Disabled
Disabled
Enabled
Fig 3
Fig 3
Int Sig: CB1OP1P
Int Sig: CB2OPANY
DDB: DTOK CB1L 1P(1552)
Fig 24
DDB: CB1 Open 3ph(903)
DDB: CB2 Open 3ph(911)
DDB: DTOK CB1L 3P(1553)
Fig 25
Fig 3
Fig 3
Int Sig: CB2OP1P
Int Sig: CB1OPANY
DDB: DTOK CB2L 1P(1442)
Fig 24
DDB: CB2 Open 3ph(911)
DDB: CB1 Open 3ph(903)
DDB: DTOK CB2L 3P(1443)
Fig 25
Setting:
NUM CBs :
CB 1 Only
CB 2 Only
Both CB1&CB2
&
1
P4117Ena

Figure AR 134 - Dead time start enable

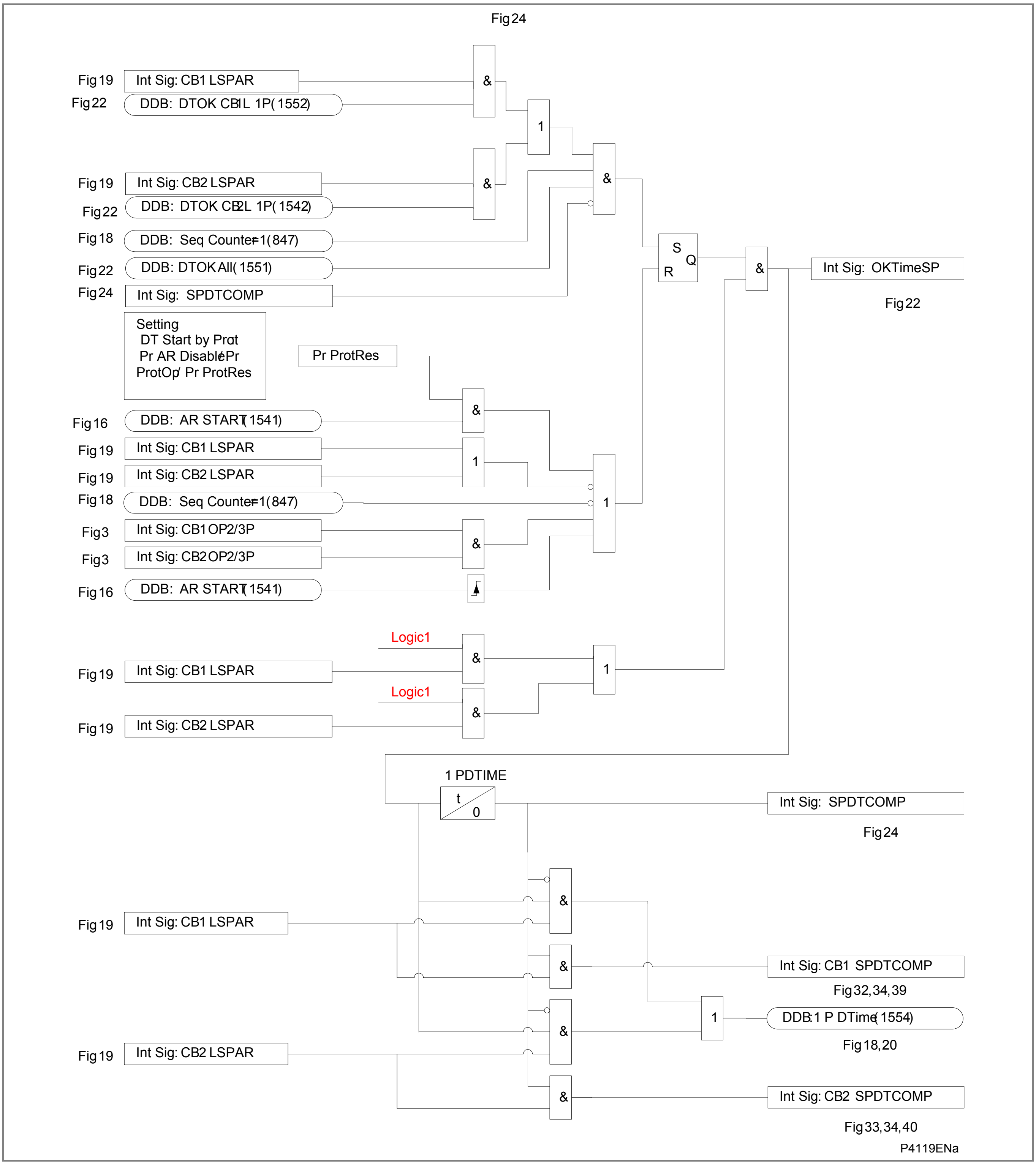


Fig 24
Fig 19
Int Sig: CB1 LSPAR
Fig 22
DDB: DTOK CB1L 1P (1552)
&
1
Fig 19
Int Sig: CB2 LSPAR
Fig 22
DDB: DTOK CB2L 1P (1542)
&
&
Fig 18
DDB: Seq Counter=1 (847)
Fig 22
DDB: DTOK All (1551)
Fig 24
Int Sig: SPDTCOMP
S
Q
R
&
Int Sig: OKTimeSP
Fig 22
Setting
DT Start by Prot
Pr AR Disable/Pr
ProtOp/ Pr ProtRes
Pr ProtRes
&
Fig 16
DDB: AR START (1541)
Fig 19
Int Sig: CB1 LSPAR
1
Fig 19
Int Sig: CB2 LSPAR
Fig 18
DDB: Seq Counter=1 (847)
1
Fig 3
Int Sig: CB1 OP2/3P
&
Fig 3
Int Sig: CB2 OP2/3P
Fig 16
DDB: AR START (1541)
Logic1
&
Fig 19
Int Sig: CB1 LSPAR
1
Logic1
&
Fig 19
Int Sig: CB2 LSPAR
1 PDTIME
t
0
Int Sig: SPDTCOMP
Fig 24
&
Fig 19
Int Sig: CB1 LSPAR
&
Int Sig: CB1 SPDTCOMP
Fig 32, 34, 39
1
DDB: 1 P DTime (1554)
&
Fig 18, 20
Fig 19
Int Sig: CB2 LSPAR
&
Int Sig: CB2 SPDTCOMP
Fig 33, 34, 40
P4119ENa

Figure AR 135 - Single phase AR lead CB dead time

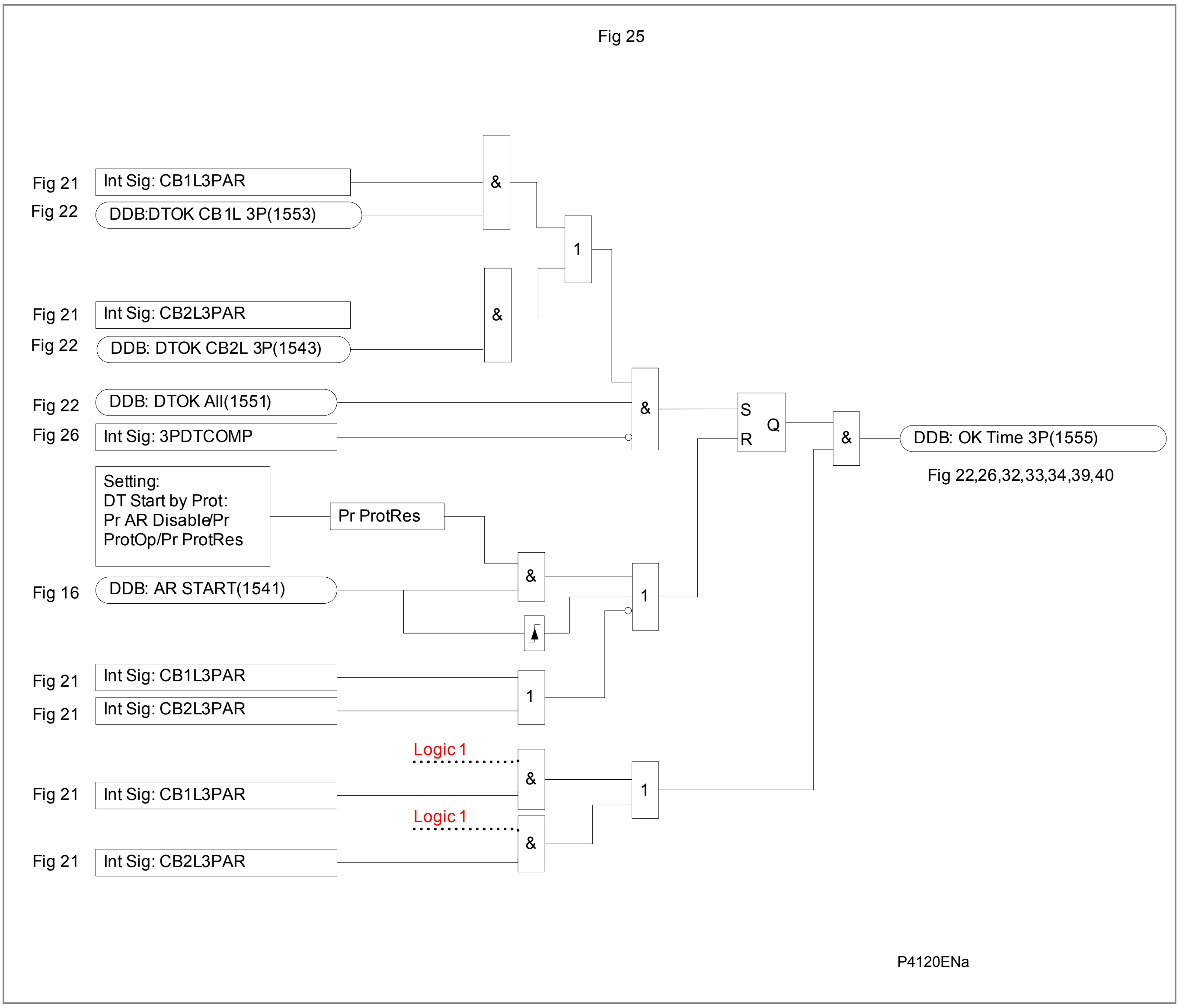


Fig 25
Fig 21
Int Sig: CB1L3PAR
Fig 22
DDB:DTOK CB1L 3P(1553)
&
1
Fig 21
Int Sig: CB2L3PAR
Fig 22
DDB: DTOK CB2L 3P(1543)
&
Fig 22
DDB: DTOK All(1551)
Fig 26
Int Sig: 3PDTCOMP
&
S
Q
R
&
DDB: OK Time 3P(1555)
Fig 22,26,32,33,34,39,40
Setting:
DT Start by Prot:
Pr AR Disable/Pr
ProtOp/Pr ProtRes
Pr ProtRes
&
1
Fig 16
DDB: AR START(1541)
Fig 21
Int Sig: CB1L3PAR
Fig 21
Int Sig: CB2L3PAR
1
Logic 1
&
1
Fig 21
Int Sig: CB1L3PAR
Logic 1
&
Fig 21
Int Sig: CB2L3PAR
P4120ENa

Figure AR 136 - Three phase AR lead CB dead time enable

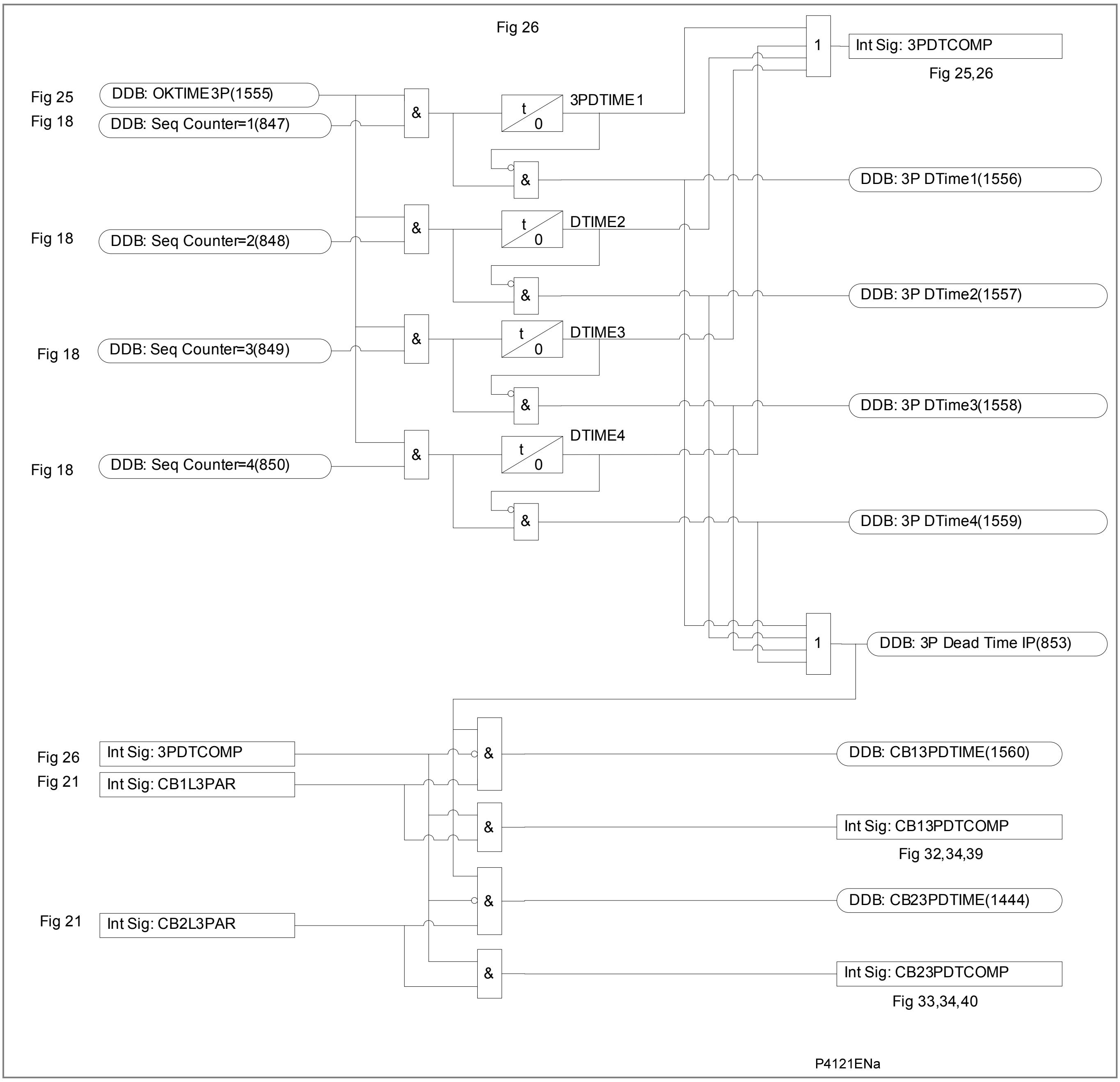


Fig 26
Fig 25
DDB: OKTIME3P(1555)
Fig 18
DDB: Seq Counter=1(847)
&
t
0
3PDTIME1
&
1
Int Sig: 3PDTCOMP
Fig 25,26
DDB: 3P DTime1(1556)
Fig 18
DDB: Seq Counter=2(848)
DTIME2
DDB: 3P DTime2(1557)
Fig 18
DDB: Seq Counter=3(849)
DTIME3
DDB: 3P DTime3(1558)
Fig 18
DDB: Seq Counter=4(850)
DTIME4
DDB: 3P DTime4(1559)
DDB: 3P Dead Time IP(853)
Fig 26
Int Sig: 3PDTCOMP
Fig 21
Int Sig: CB1L3PAR
DDB: CB13PDTIME(1560)
Int Sig: CB13PDTCOMP
Fig 32,34,39
Fig 21
Int Sig: CB2L3PAR
DDB: CB23PDTIME(1444)
Int Sig: CB23PDTCOMP
Fig 33,34,40
P4121ENa

Figure AR 137 - Three phase AR Lead CB dead time

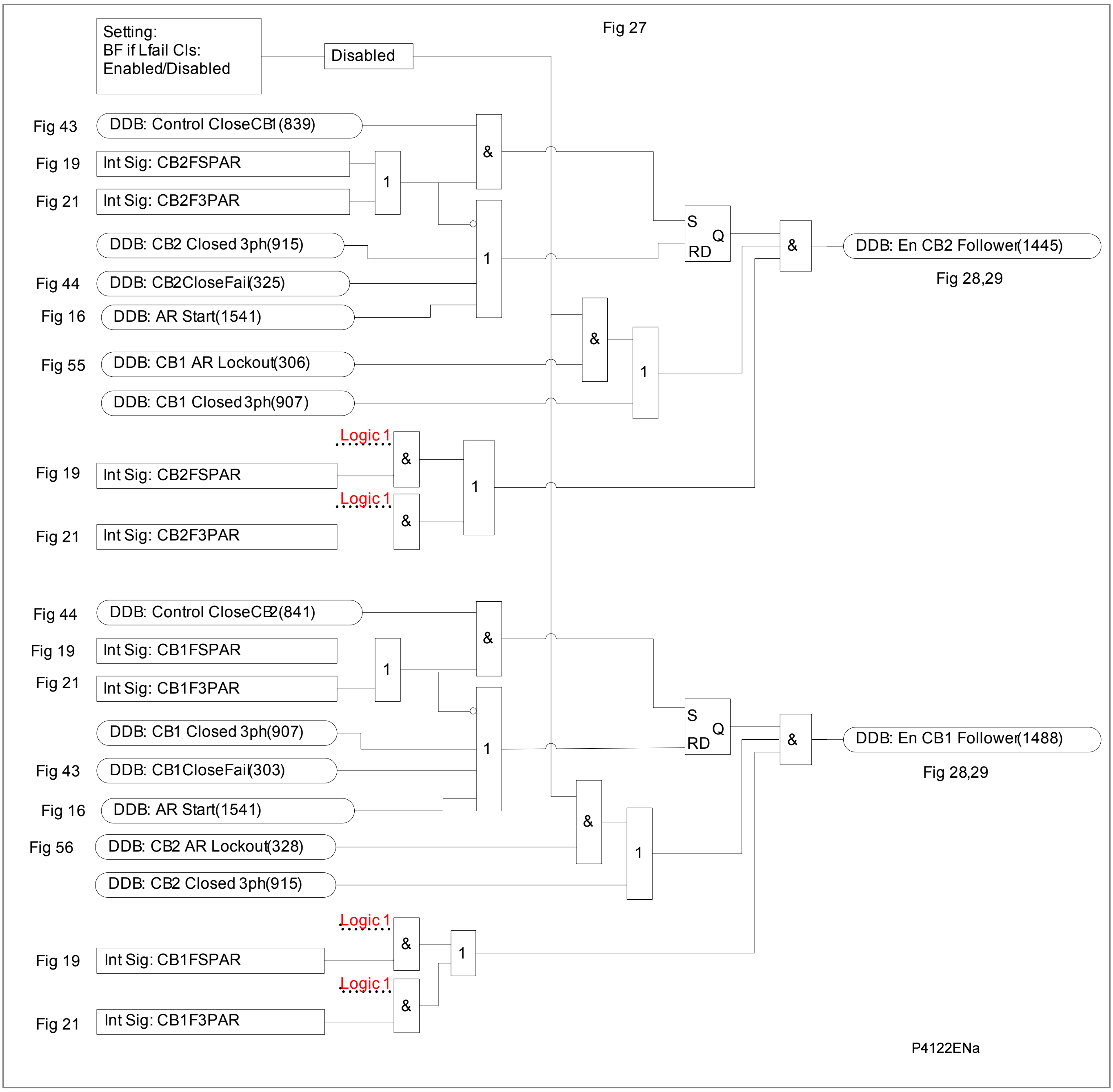

Setting:
BF if Lfail Cls:
Enabled/Disabled
Disabled
Fig 27
Fig 43
DDB: Control CloseCB1 (839)
Fig 19
Int Sig: CB2FSPAR
Fig 21
Int Sig: CB2F3PAR
DDB: CB2 Closed 3ph(915)
Fig 44
DDB: CB2CloseFail(325)
Fig 16
DDB: AR Start(1541)
Fig 55
DDB: CB1 AR Lockout(306)
DDB: CB1 Closed 3ph(907)
Logic 1
Fig 19
Int Sig: CB2FSPAR
Logic 1
Fig 21
Int Sig: CB2F3PAR
S
Q
RD
&
1
DDB: En CB2 Follower(1445)
Fig 28,29
Fig 44
DDB: Control CloseCB2(841)
Fig 19
Int Sig: CB1FSPAR
Fig 21
Int Sig: CB1F3PAR
DDB: CB1 Closed 3ph(907)
Fig 43
DDB: CB1CloseFail(303)
Fig 16
DDB: AR Start(1541)
Fig 56
DDB: CB2 AR Lockout(328)
DDB: CB2 Closed 3ph(915)
Logic 1
Fig 19
Int Sig: CB1FSPAR
Logic 1
Fig 21
Int Sig: CB1F3PAR
DDB: En CB1 Follower(1488)
Fig 28,29
P4122ENa

Figure AR 138 - Follower AR enable

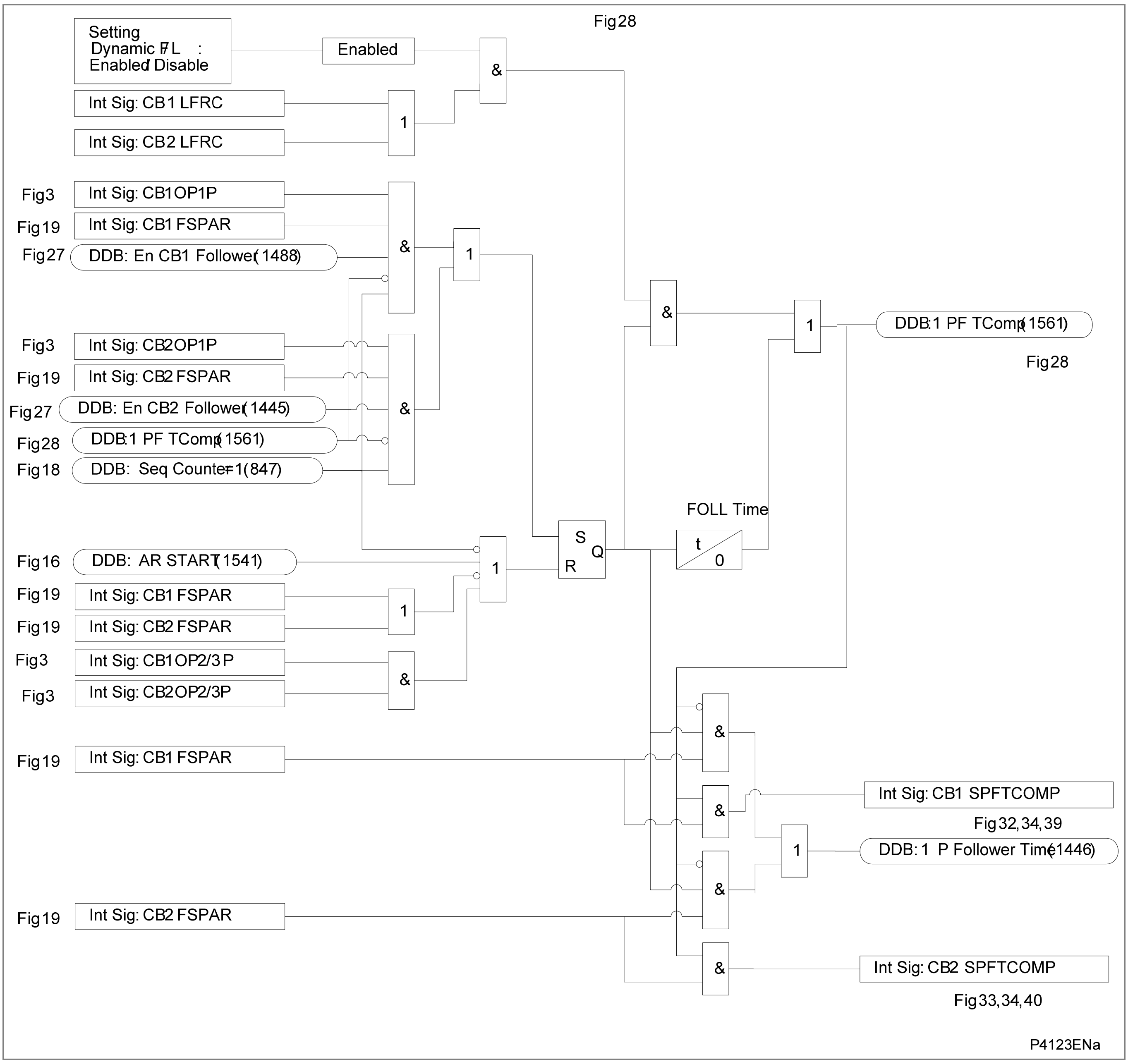

Setting
Dynamic F/L :
Enabled/ Disable
Enabled
&
Int Sig: CB1 LFRC
Int Sig: CB2 LFRC
1
Fig28
Fig3
Int Sig: CB1OP1P
Fig19
Int Sig: CB1 FSPAR
Fig27
DDB: En CB1 Follower(1488)
&
1
Fig3
Int Sig: CB2OP1P
Fig19
Int Sig: CB2 FSPAR
Fig27
DDB: En CB2 Follower(1445)
Fig28
DDB:1 PF TComp(1561)
Fig18
DDB: Seq Counter=1(847)
&
&
1
DDB:1 PF TComp(1561)
Fig28
FOLL Time
S
Q
R
t
0
Fig16
DDB: AR START(1541)
1
Fig19
Int Sig: CB1 FSPAR
Fig19
Int Sig: CB2 FSPAR
1
Fig3
Int Sig: CB1OP2/3P
Fig3
Int Sig: CB2OP2/3P
&
Fig19
Int Sig: CB1 FSPAR
&
&
Int Sig: CB1 SPFTCOMP
Fig32,34,39
1
DDB: 1 P Follower Time(1446)
&
Fig19
Int Sig: CB2 FSPAR
&
Int Sig: CB2 SPFTCOMP
Fig33,34,40
P4123ENa

Figure AR 139 - Single phase follower time

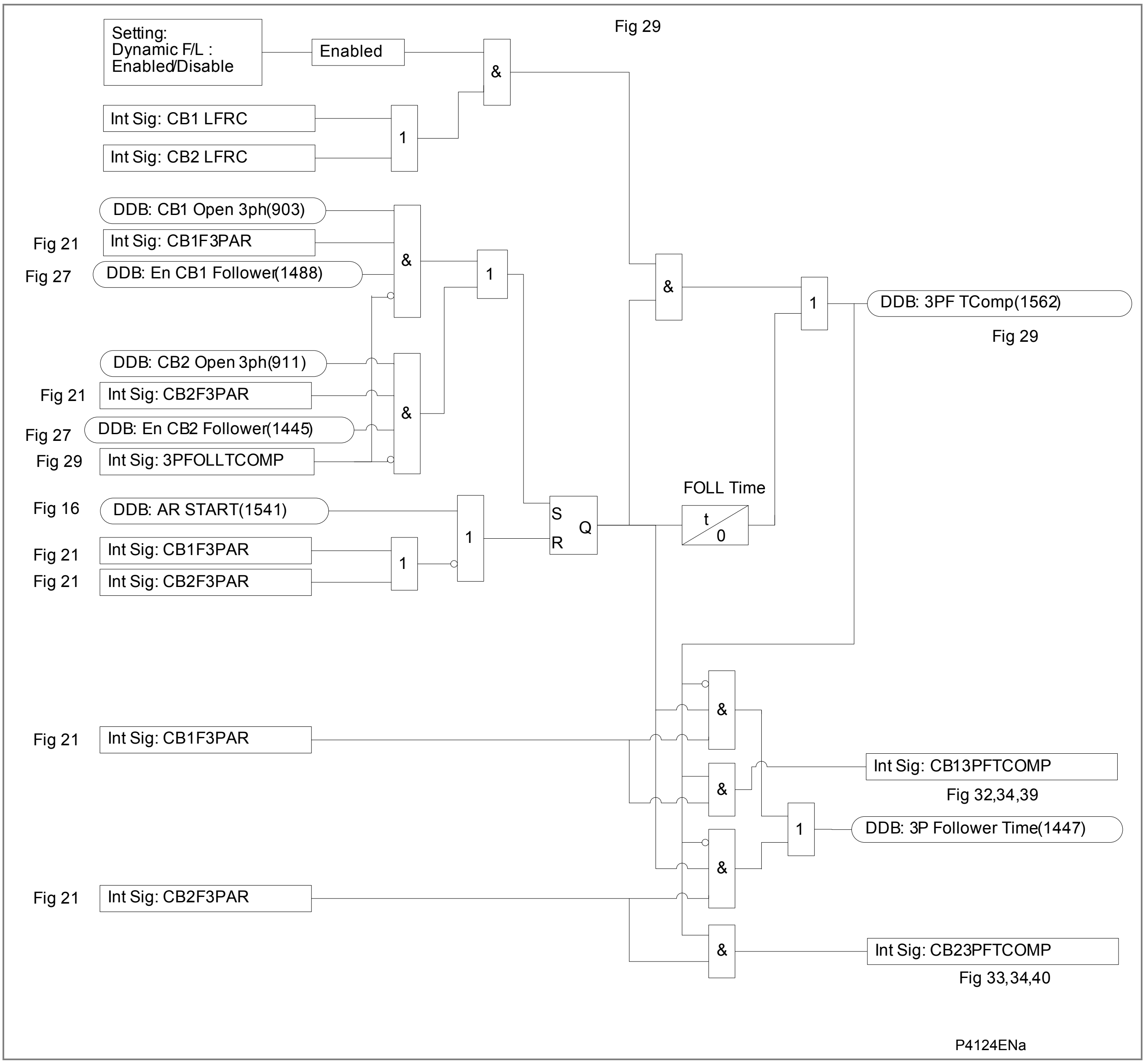

Setting:
Dynamic F/L :
Enabled/Disable
Enabled
&
Fig 29
Int Sig: CB1 LFRC
Int Sig: CB2 LFRC
1
DDB: CB1 Open 3ph(903)
Fig 21
Int Sig: CB1F3PAR
Fig 27
DDB: En CB1 Follower(1488)
&
1
&
1
DDB: 3PF TComp(1562)
Fig 29
DDB: CB2 Open 3ph(911)
Fig 21
Int Sig: CB2F3PAR
Fig 27
DDB: En CB2 Follower(1445)
&
Fig 29
Int Sig: 3PFOLLTCOMP
Fig 16
DDB: AR START(1541)
FOLL Time
S
Q
R
t
0
1
Fig 21
Int Sig: CB1F3PAR
1
Fig 21
Int Sig: CB2F3PAR
&
Fig 21
Int Sig: CB1F3PAR
&
Int Sig: CB13PFTCOMP
Fig 32,34,39
1
DDB: 3P Follower Time(1447)
&
Fig 21
Int Sig: CB2F3PAR
&
Int Sig: CB23PFTCOMP
Fig 33,34,40
P4124ENa

Figure AR 140 - Three phase follower time

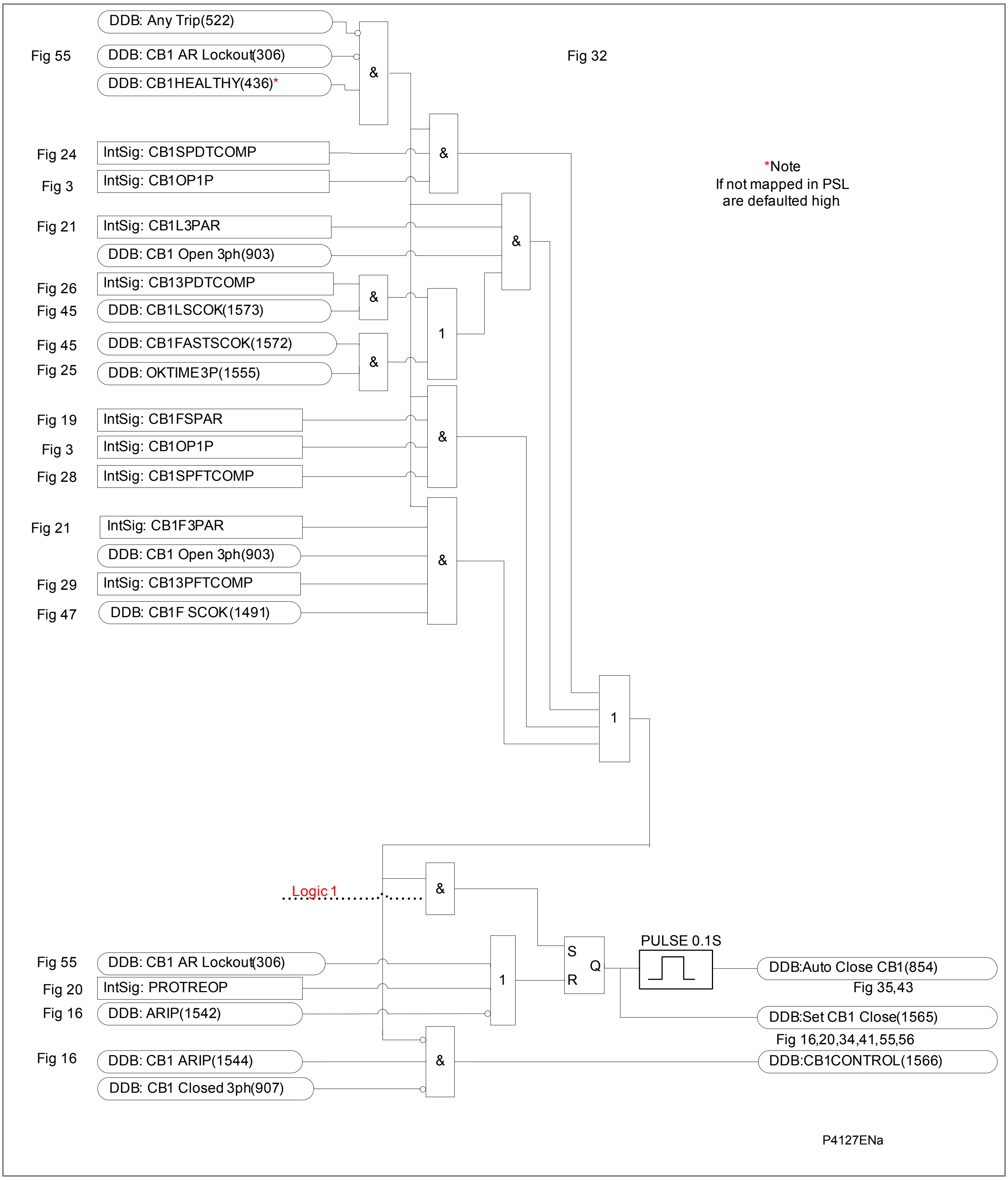

DDB: Any Trip(522)
Fig 55
DDB: CB1 AR Lockout(306)
DDB: CB1HEALTHY(436)*
&
Fig 32
Fig 24
IntSig: CB1SPDTCOMP
Fig 3
IntSig: CB1OP1P
&
*Note
If not mapped in PSL
are defaulted high
Fig 21
IntSig: CB1L3PAR
DDB: CB1 Open 3ph(903)
&
Fig 26
IntSig: CB13PDTCOMP
Fig 45
DDB: CB1LSCOK(1573)
&
1
Fig 45
DDB: CB1FASTSCOK(1572)
Fig 25
DDB: OKTIME3P(1555)
&
Fig 19
IntSig: CB1FSPAR
Fig 3
IntSig: CB1OP1P
Fig 28
IntSig: CB1SPFTCOMP
&
Fig 21
IntSig: CB1F3PAR
DDB: CB1 Open 3ph(903)
Fig 29
IntSig: CB13PFTCOMP
Fig 47
DDB: CB1F SCOK(1491)
&
1
Logic 1
&
Fig 55
DDB: CB1 AR Lockout(306)
Fig 20
IntSig: PROTREOP
Fig 16
DDB: ARIP(1542)
1
S
R
Q
PULSE 0.1S
DDB:Auto Close CB1(854)
Fig 35,43
DDB:Set CB1 Close(1565)
Fig 16,20,34,41,55,56
Fig 16
DDB: CB1 ARIP(1544)
DDB: CB1 Closed 3ph(907)
&
DDB:CB1CONTROL(1566)
P4127ENa

Figure AR 141 - CB1 auto close

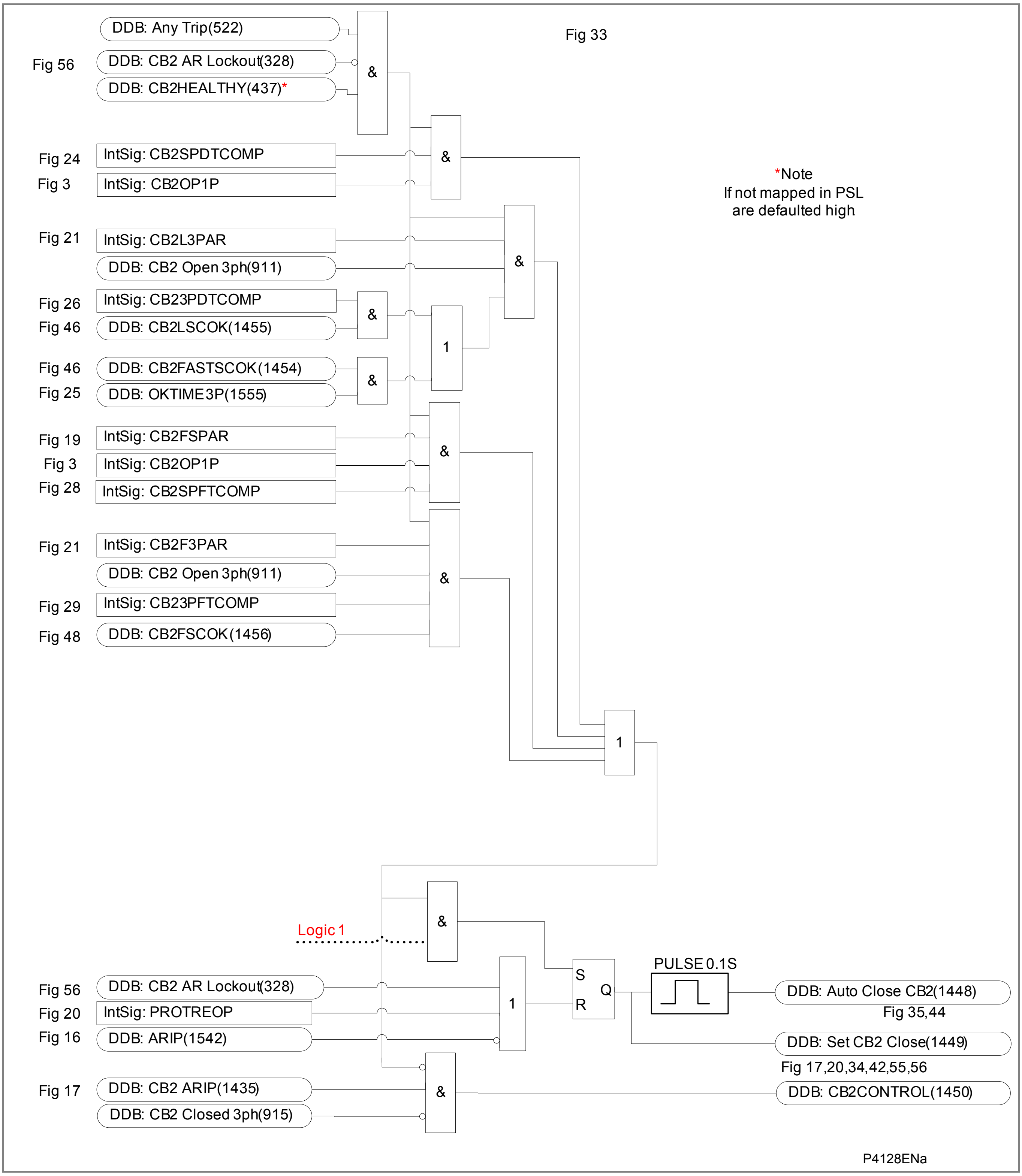

DDB: Any Trip(522)
Fig 56
DDB: CB2 AR Lockout(328)
DDB: CB2HEALTHY(437)*
&
Fig 33
Fig 24
IntSig: CB2SPDTCOMP
Fig 3
IntSig: CB2OP1P
*Note
If not mapped in PSL
are defaulted high
Fig 21
IntSig: CB2L3PAR
DDB: CB2 Open 3ph(911)
Fig 26
IntSig: CB23PDTCOMP
Fig 46
DDB: CB2LSCOK(1455)
Fig 46
DDB: CB2FASTSCOK(1454)
Fig 25
DDB: OKTIME3P(1555)
1
Fig 19
IntSig: CB2FSPAR
Fig 3
IntSig: CB2OP1P
Fig 28
IntSig: CB2SPFTCOMP
Fig 21
IntSig: CB2F3PAR
DDB: CB2 Open 3ph(911)
Fig 29
IntSig: CB23PFTCOMP
Fig 48
DDB: CB2FSCOK(1456)
Logic 1
S
Q
R
PULSE 0.1S
Fig 56
DDB: CB2 AR Lockout(328)
Fig 20
IntSig: PROTREOP
Fig 16
DDB: ARIP(1542)
DDB: Auto Close CB2(1448)
Fig 35,44
DDB: Set CB2 Close(1449)
Fig 17,20,34,42,55,56
Fig 17
DDB: CB2 ARIP(1435)
DDB: CB2 Closed 3ph(915)
DDB: CB2CONTROL(1450)
P4128ENa

Figure AR 142 - CB2 auto close

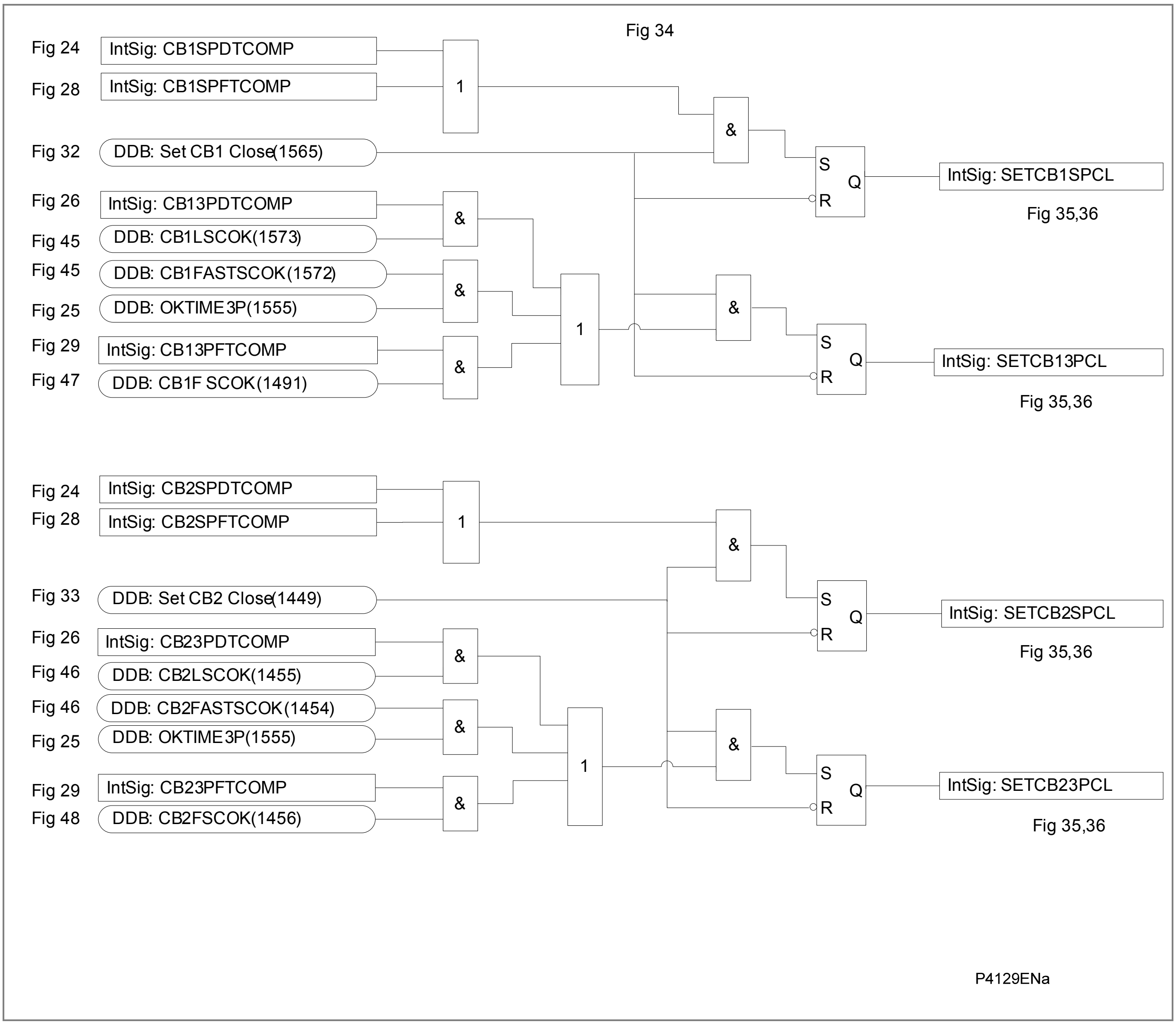


Fig 34
Fig 24
IntSig: CB1SPDTCOMP
Fig 28
IntSig: CB1SPFTCOMP
Fig 32
DDB: Set CB1 Close(1565)
Fig 26
IntSig: CB13PDTCOMP
Fig 45
DDB: CB1LSCOK(1573)
Fig 45
DDB: CB1FASTSCOK(1572)
Fig 25
DDB: OKTIME3P(1555)
Fig 29
IntSig: CB13PFTCOMP
Fig 47
DDB: CB1F SCOK(1491)
IntSig: SETCB1SPCL
Fig 35,36
IntSig: SETCB13PCL
Fig 35,36
Fig 24
IntSig: CB2SPDTCOMP
Fig 28
IntSig: CB2SPFTCOMP
Fig 33
DDB: Set CB2 Close(1449)
Fig 26
IntSig: CB23PDTCOMP
Fig 46
DDB: CB2LSCOK(1455)
Fig 46
DDB: CB2FASTSCOK(1454)
Fig 25
DDB: OKTIME3P(1555)
Fig 29
IntSig: CB23PFTCOMP
Fig 48
DDB: CB2FSCOK(1456)
IntSig: SETCB2SPCL
Fig 35,36
IntSig: SETCB23PCL
Fig 35,36
1
&
S
R
Q
P4129ENa

Figure AR 143 - Prepare reclaim initiation

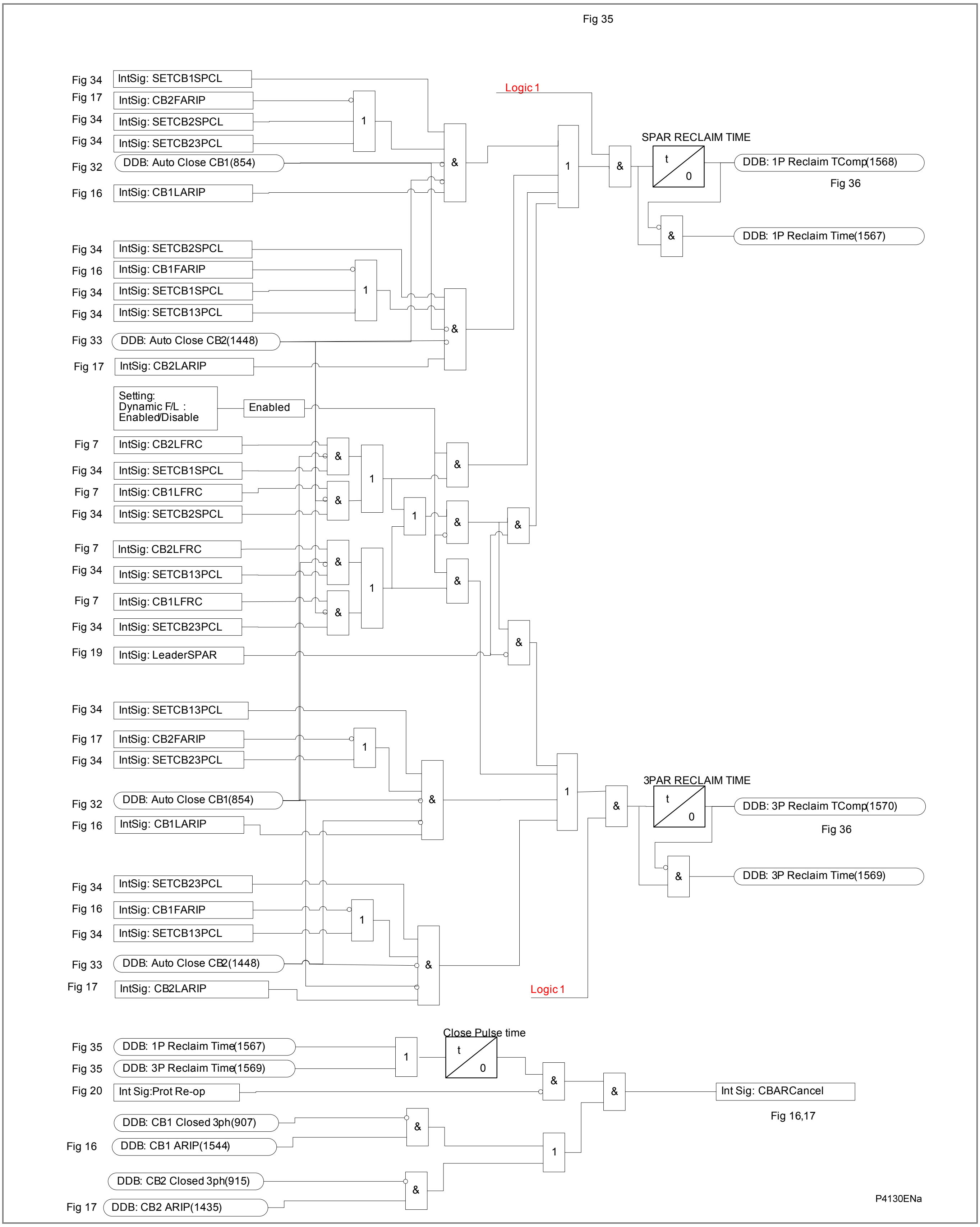


Fig 35
Fig 34
IntSig: SETCB1SPCL
Fig 17
IntSig: CB2FARIP
Fig 34
IntSig: SETCB2SPCL
Fig 34
IntSig: SETCB23PCL
Fig 32
DDB: Auto Close CB1(854)
Fig 16
IntSig: CB1LARIP
Logic 1
SPAR RECLAIM TIME
t
0
DDB: 1P Reclaim TComp(1568)
Fig 36
DDB: 1P Reclaim Time(1567)
Fig 34
IntSig: SETCB2SPCL
Fig 16
IntSig: CB1FARIP
Fig 34
IntSig: SETCB1SPCL
Fig 34
IntSig: SETCB13PCL
Fig 33
DDB: Auto Close CB2(1448)
Fig 17
IntSig: CB2LARIP
Setting:
Dynamic F/L :
Enabled/Disable
Enabled
Fig 7
IntSig: CB2LFRC
Fig 34
IntSig: SETCB1SPCL
Fig 7
IntSig: CB1LFRC
Fig 34
IntSig: SETCB2SPCL
Fig 7
IntSig: CB2LFRC
Fig 34
IntSig: SETCB13PCL
Fig 7
IntSig: CB1LFRC
Fig 34
IntSig: SETCB23PCL
Fig 19
IntSig: LeaderSPAR
Fig 34
IntSig: SETCB13PCL
Fig 17
IntSig: CB2FARIP
Fig 34
IntSig: SETCB23PCL
Fig 32
DDB: Auto Close CB1(854)
Fig 16
IntSig: CB1LARIP
3PAR RECLAIM TIME
t
0
DDB: 3P Reclaim TComp(1570)
Fig 36
DDB: 3P Reclaim Time(1569)
Fig 34
IntSig: SETCB23PCL
Fig 16
IntSig: CB1FARIP
Fig 34
IntSig: SETCB13PCL
Fig 33
DDB: Auto Close CB2(1448)
Fig 17
IntSig: CB2LARIP
Logic 1
Fig 35
DDB: 1P Reclaim Time(1567)
Fig 35
DDB: 3P Reclaim Time(1569)
Fig 20
Int Sig:Prot Re-op
Close Pulse time
t
0
Int Sig: CBARCancel
Fig 16,17
DDB: CB1 Closed 3ph(907)
Fig 16
DDB: CB1 ARIP(1544)
DDB: CB2 Closed 3ph(915)
Fig 17
DDB: CB2 ARIP(1435)
&
1
P4130ENa

Figure AR 144 - Reclaim time

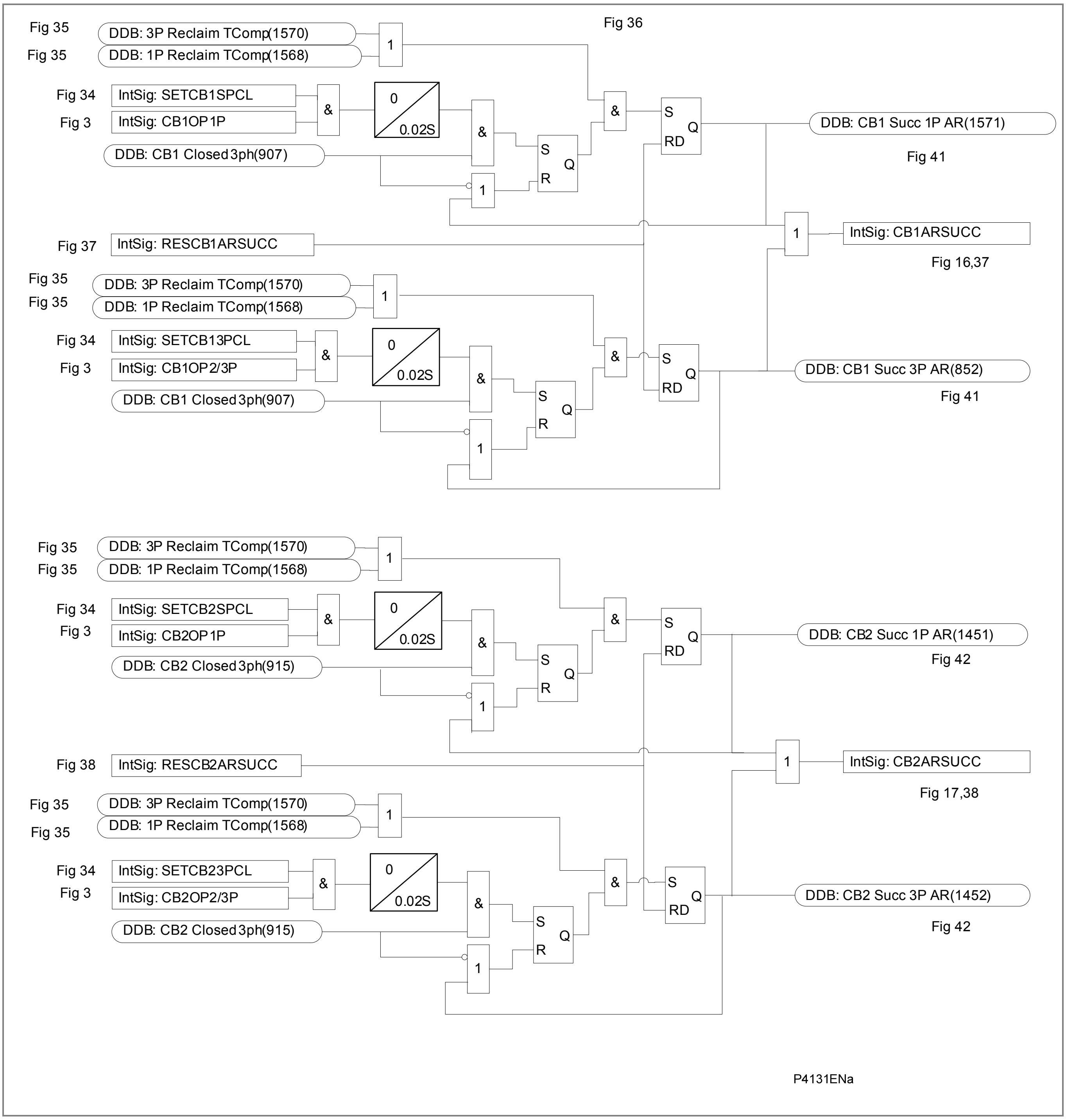


Fig 35
DDB: 3P Reclaim TComp(1570)
Fig 35
DDB: 1P Reclaim TComp(1568)
Fig 34
IntSig: SETCB1SPCL
Fig 3
IntSig: CB1OP1P
DDB: CB1 Closed 3ph(907)
0.02S
Fig 36
DDB: CB1 Succ 1P AR(1571)
Fig 41
Fig 37
IntSig: RESCB1ARSUCC
IntSig: CB1ARSUCC
Fig 16,37
Fig 35
DDB: 3P Reclaim TComp(1570)
Fig 35
DDB: 1P Reclaim TComp(1568)
Fig 34
IntSig: SETCB13PCL
Fig 3
IntSig: CB1OP2/3P
DDB: CB1 Closed 3ph(907)
DDB: CB1 Succ 3P AR(852)
Fig 41
Fig 35
DDB: 3P Reclaim TComp(1570)
Fig 35
DDB: 1P Reclaim TComp(1568)
Fig 34
IntSig: SETCB2SPCL
Fig 3
IntSig: CB2OP1P
DDB: CB2 Closed 3ph(915)
DDB: CB2 Succ 1P AR(1451)
Fig 42
Fig 38
IntSig: RESCB2ARSUCC
IntSig: CB2ARSUCC
Fig 17,38
Fig 35
DDB: 3P Reclaim TComp(1570)
Fig 35
DDB: 1P Reclaim TComp(1568)
Fig 34
IntSig: SETCB23PCL
Fig 3
IntSig: CB2OP2/3P
DDB: CB2 Closed 3ph(915)
DDB: CB2 Succ 3P AR(1452)
Fig 42
P4131ENa

Figure AR 145 - Successful auto-reclose signals

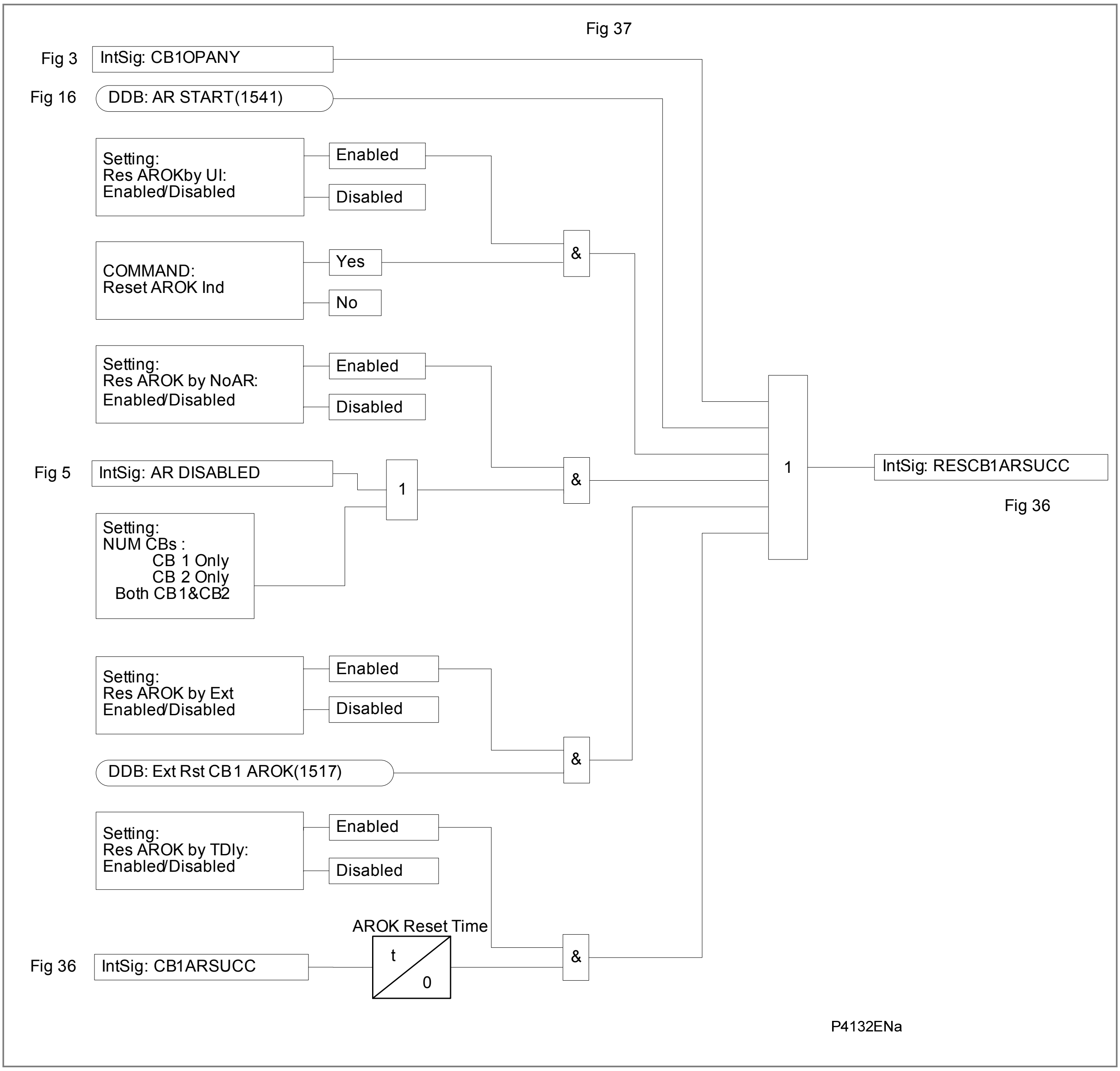


Fig 37
Fig 3
IntSig: CB1OPANY
Fig 16
DDB: AR START(1541)
Setting:
Res AROKby UI:
Enabled/Disabled
Enabled
Disabled
COMMAND:
Reset AROK Ind
Yes
No
&
Setting:
Res AROK by NoAR:
Enabled/Disabled
Enabled
Disabled
Fig 5
IntSig: AR DISABLED
1
&
1
IntSig: RESCB1ARSUCC
Fig 36
Setting:
NUM CBs :
CB 1 Only
CB 2 Only
Both CB1&CB2
Setting:
Res AROK by Ext
Enabled/Disabled
Enabled
Disabled
&
DDB: Ext Rst CB1 AROK(1517)
Setting:
Res AROK by TDly:
Enabled/Disabled
Enabled
Disabled
AROK Reset Time
t
0
&
Fig 36
IntSig: CB1ARSUCC
P4132ENa

Figure AR 146 - Reset CB1 successful AR indication

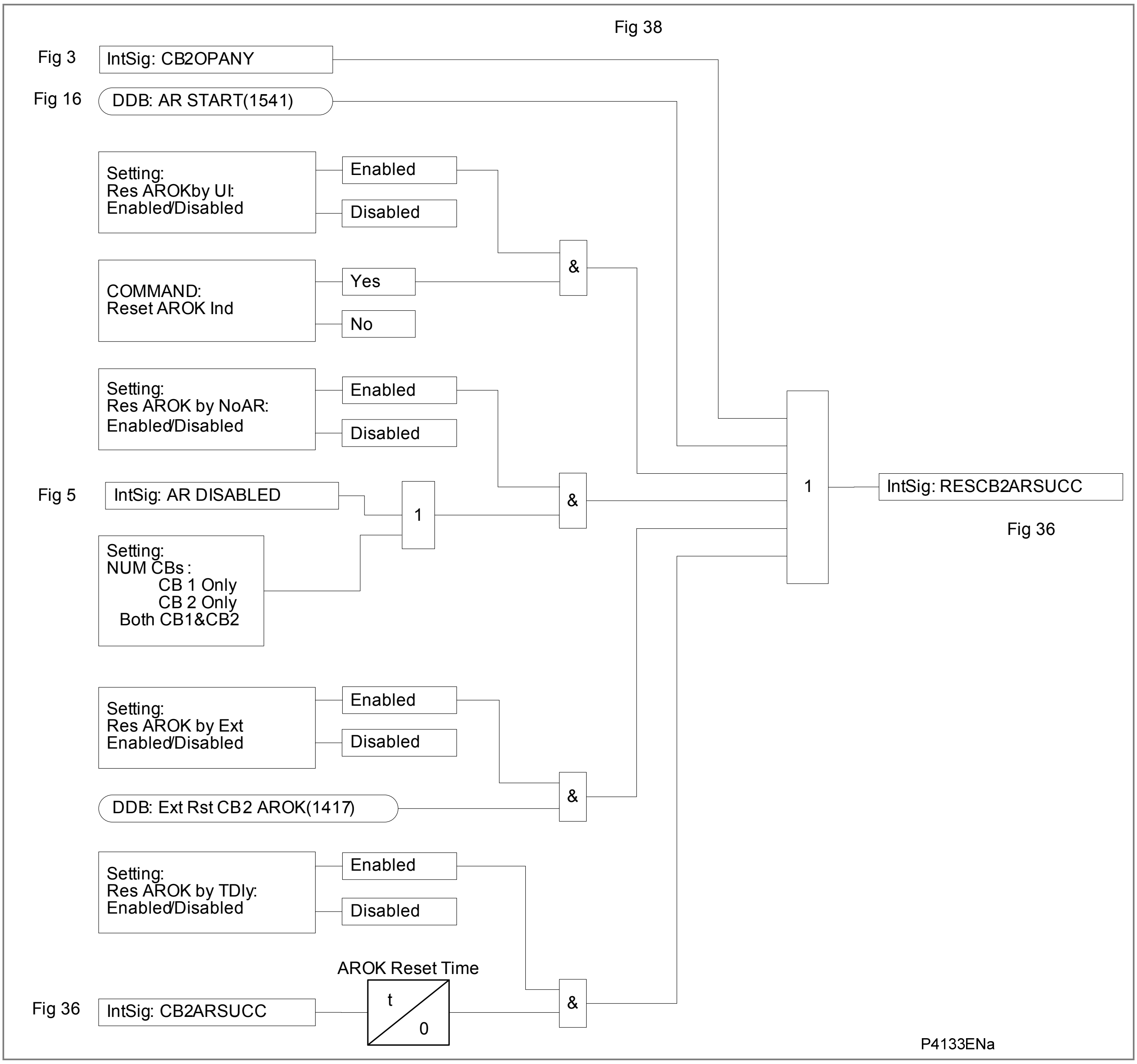


Fig 38
Fig 3
IntSig: CB2OPANY
Fig 16
DDB: AR START(1541)
Setting:
Res AROKby UI:
Enabled/Disabled
Enabled
Disabled
&
COMMAND:
Reset AROK Ind
Yes
No
Setting:
Res AROK by NoAR:
Enabled/Disabled
Enabled
Disabled
Fig 5
IntSig: AR DISABLED
1
&
1
IntSig: RESCB2ARSUCC
Fig 36
Setting:
NUM CBs :
CB 1 Only
CB 2 Only
Both CB1&CB2
Setting:
Res AROK by Ext
Enabled/Disabled
Enabled
Disabled
&
DDB: Ext Rst CB2 AROK(1417)
Setting:
Res AROK by TDly:
Enabled/Disabled
Enabled
Disabled
AROK Reset Time
t
0
&
Fig 36
IntSig: CB2ARSUCC
P4133ENa

Figure AR 147 - Reset CB2 successful AR indication

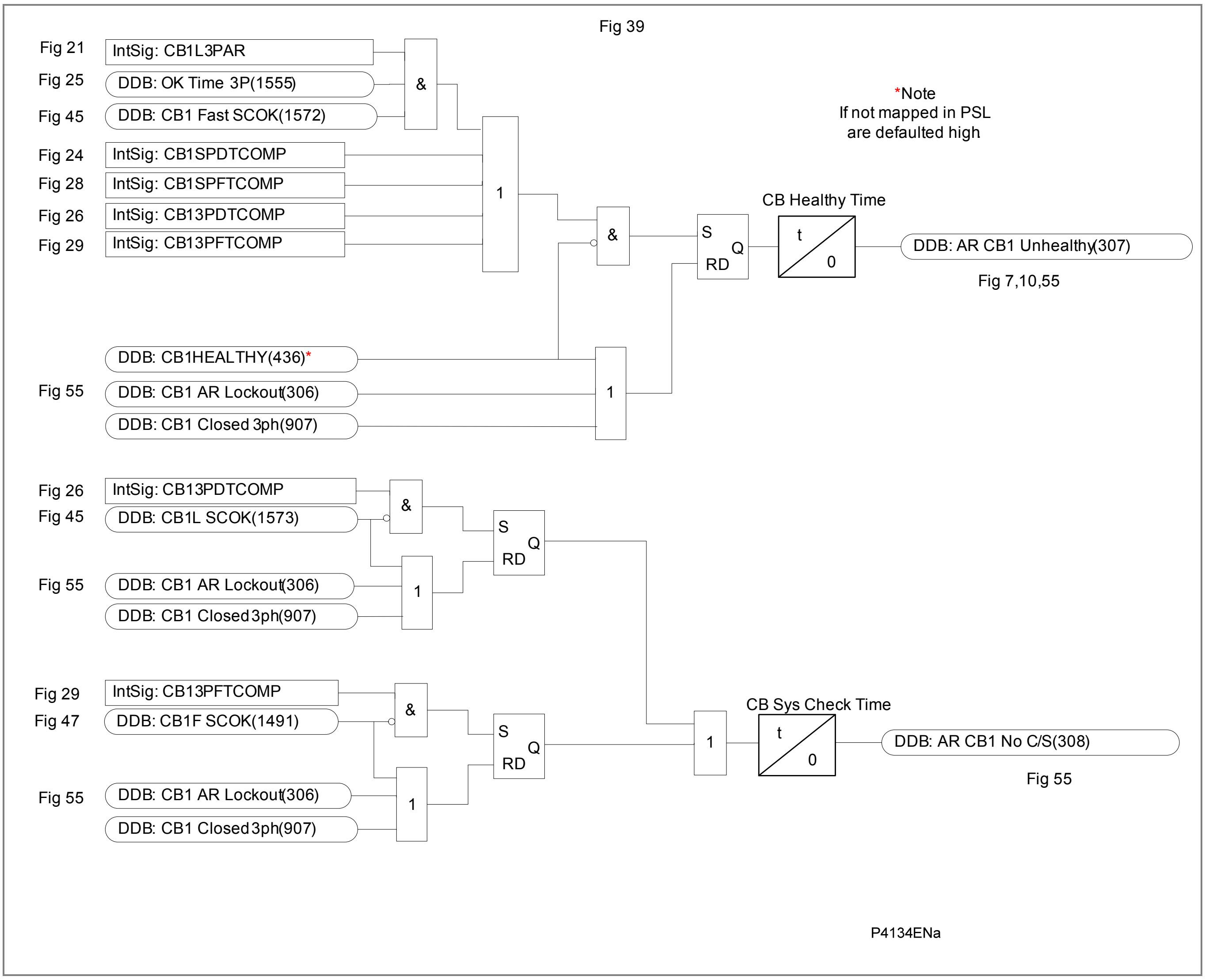


Fig 39
Fig 21
IntSig: CB1L3PAR
Fig 25
DDB: OK Time 3P(1555)
Fig 45
DDB: CB1 Fast SCOK(1572)
&
Fig 24
IntSig: CB1SPDTCOMP
Fig 28
IntSig: CB1SPFTCOMP
Fig 26
IntSig: CB13PDTCOMP
Fig 29
IntSig: CB13PFTCOMP
1
&
*Note
If not mapped in PSL
are defaulted high
CB Healthy Time
S
Q
RD
t
0
DDB: AR CB1 Unhealthy(307)
Fig 7,10,55
DDB: CB1HEALTHY(436)*
Fig 55
DDB: CB1 AR Lockout(306)
DDB: CB1 Closed 3ph(907)
1
Fig 26
IntSig: CB13PDTCOMP
Fig 45
DDB: CB1L SCOK(1573)
&
S
Q
RD
Fig 55
DDB: CB1 AR Lockout(306)
DDB: CB1 Closed 3ph(907)
1
Fig 29
IntSig: CB13PFTCOMP
Fig 47
DDB: CB1F SCOK(1491)
&
S
Q
RD
CB Sys Check Time
1
t
0
DDB: AR CB1 No C/S(308)
Fig 55
Fig 55
DDB: CB1 AR Lockout(306)
DDB: CB1 Closed 3ph(907)
1
P4134ENa

Figure AR 148 - CB1 healthy and system check timers

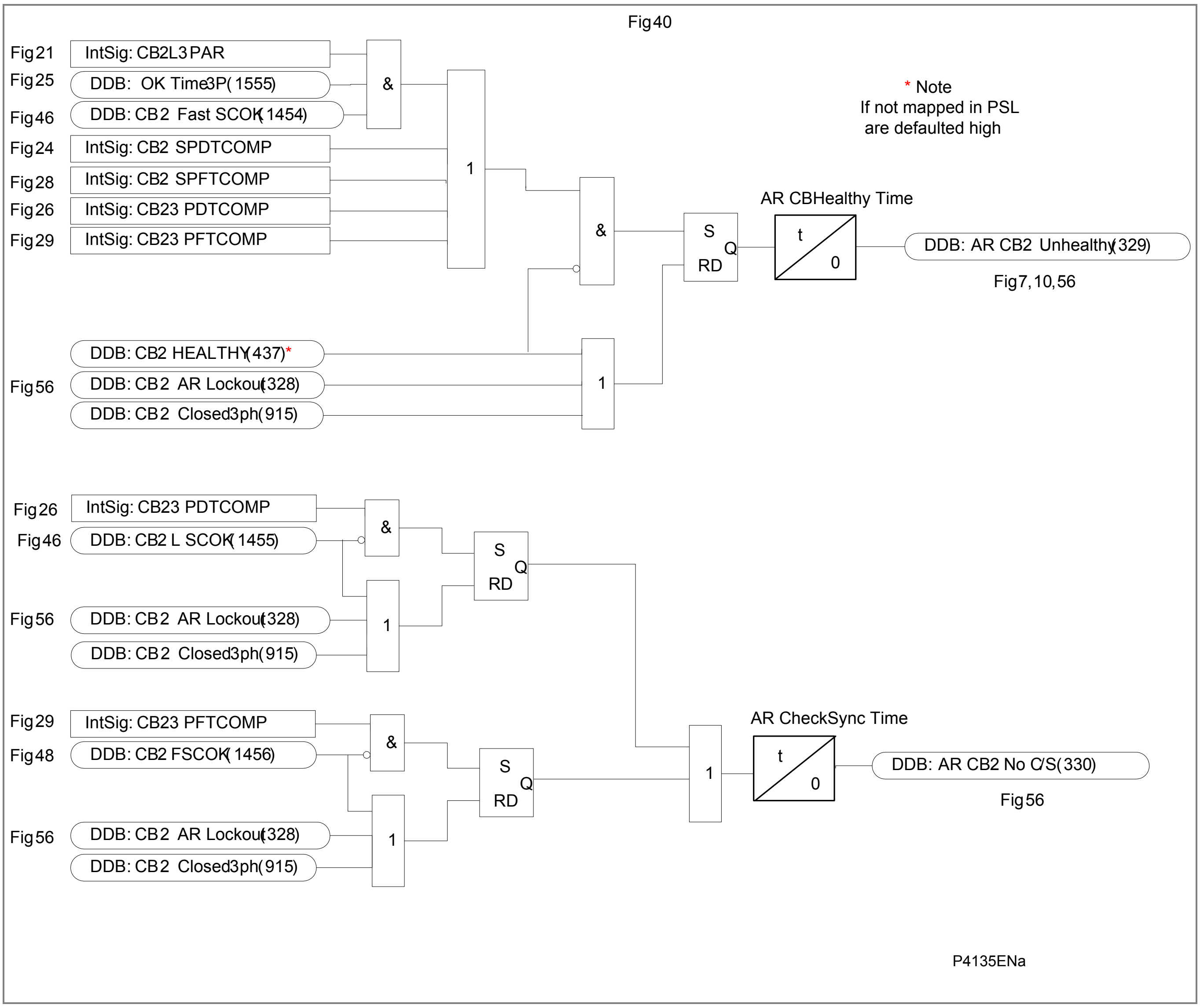


Fig40
Fig21
IntSig: CB2L3PAR
Fig25
DDB: OK Time3P(1555)
Fig46
DDB: CB2 Fast SCOK(1454)
Fig24
IntSig: CB2 SPDTCOMP
Fig28
IntSig: CB2 SPFTCOMP
Fig26
IntSig: CB23 PDTCOMP
Fig29
IntSig: CB23 PFTCOMP
&
1
&
S
Q
RD
* Note
If not mapped in PSL
are defaulted high
AR CBHealthy Time
t
0
DDB: AR CB2 Unhealthy(329)
Fig7, 10, 56
DDB: CB2 HEALTHY(437)*
Fig56
DDB: CB2 AR Lockout(328)
DDB: CB2 Closed3ph(915)
1
Fig26
IntSig: CB23 PDTCOMP
Fig46
DDB: CB2 L SCOK(1455)
&
S
Q
RD
Fig56
DDB: CB2 AR Lockout(328)
DDB: CB2 Closed3ph(915)
1
Fig29
IntSig: CB23 PFTCOMP
Fig48
DDB: CB2 FSCOK(1456)
&
S
Q
RD
Fig56
DDB: CB2 AR Lockout(328)
DDB: CB2 Closed3ph(915)
1
1
AR CheckSync Time
t
0
DDB: AR CB2 No C/S(330)
Fig56
P4135ENa

Figure AR 149 - CB2 healthy and system check timers

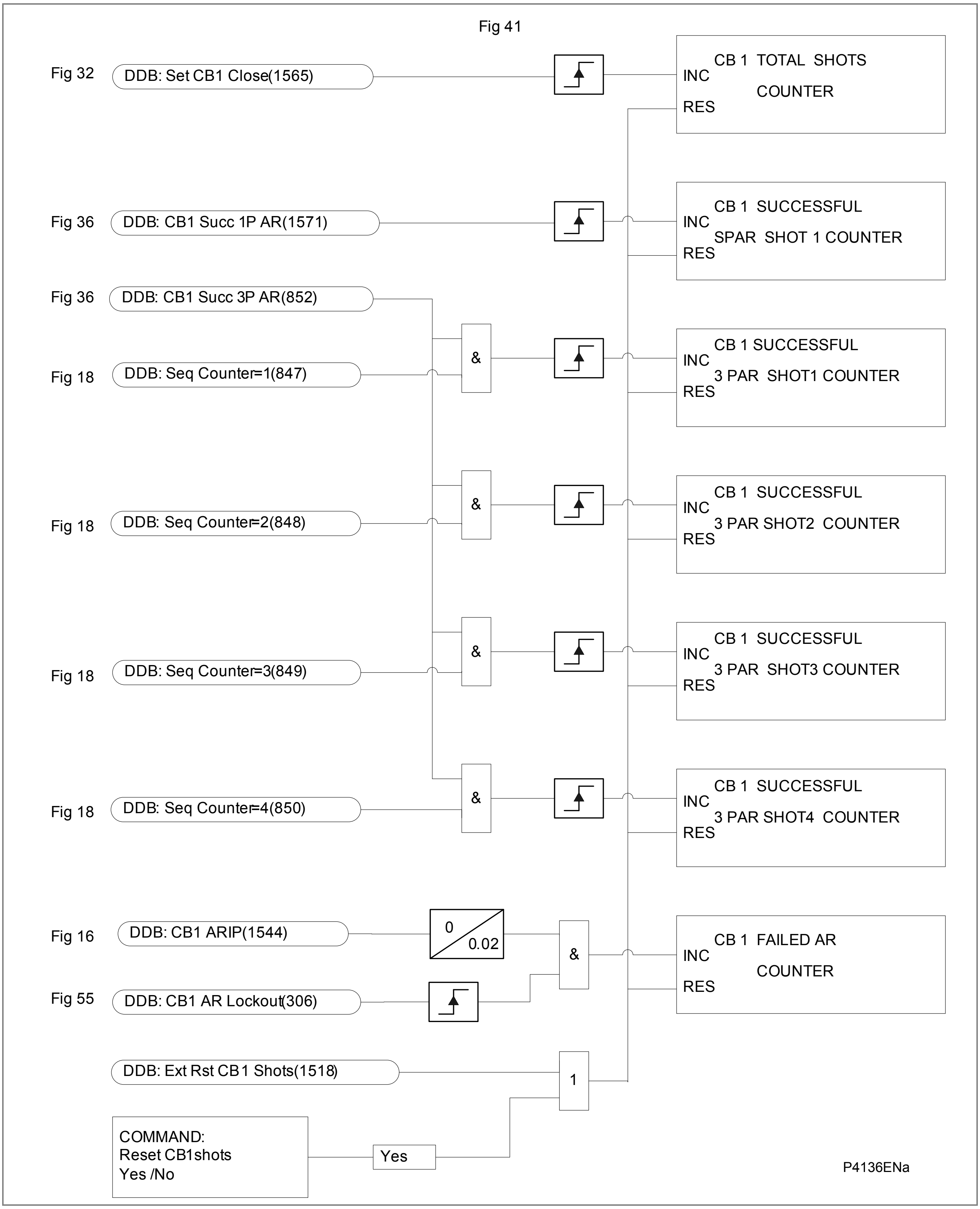


Fig 41
Fig 32
DDB: Set CB1 Close(1565)
CB 1 TOTAL SHOTS COUNTER
INC
RES
Fig 36
DDB: CB1 Succ 1P AR(1571)
CB 1 SUCCESSFUL SPAR SHOT 1 COUNTER
Fig 36
DDB: CB1 Succ 3P AR(852)
Fig 18
DDB: Seq Counter=1(847)
&
CB 1 SUCCESSFUL 3 PAR SHOT1 COUNTER
Fig 18
DDB: Seq Counter=2(848)
CB 1 SUCCESSFUL 3 PAR SHOT2 COUNTER
Fig 18
DDB: Seq Counter=3(849)
CB 1 SUCCESSFUL 3 PAR SHOT3 COUNTER
Fig 18
DDB: Seq Counter=4(850)
CB 1 SUCCESSFUL 3 PAR SHOT4 COUNTER
Fig 16
DDB: CB1 ARIP(1544)
0
0.02
Fig 55
DDB: CB1 AR Lockout(306)
CB 1 FAILED AR COUNTER
DDB: Ext Rst CB1 Shots(1518)
1
COMMAND: Reset CB1shots Yes /No
Yes
P4136ENa

Figure AR 150 - CB1 AR shots counters

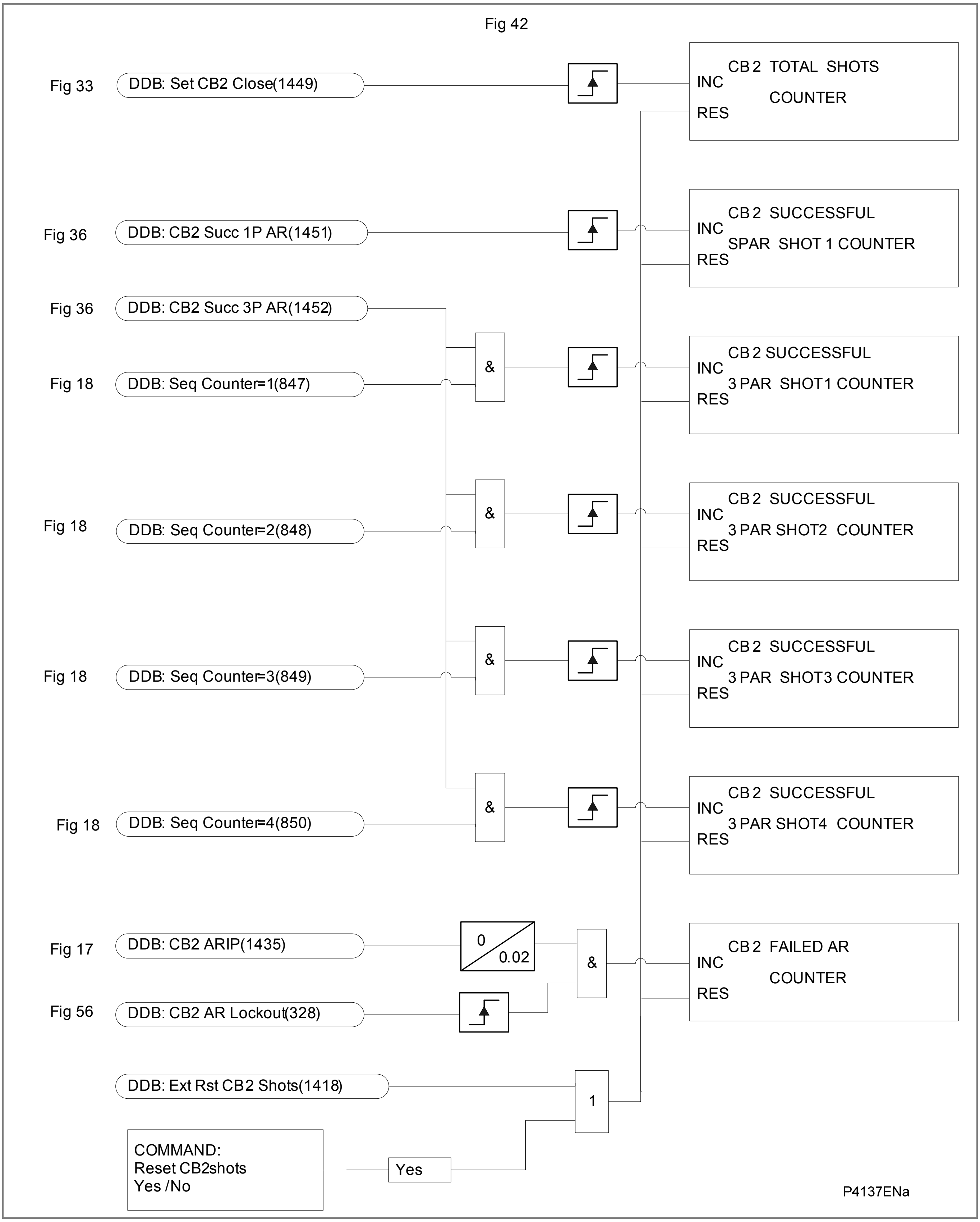


Fig 42
Fig 33
DDB: Set CB2 Close(1449)
CB2 TOTAL SHOTS COUNTER
INC
RES
Fig 36
DDB: CB2 Succ 1P AR(1451)
CB2 SUCCESSFUL SPAR SHOT 1 COUNTER
Fig 36
DDB: CB2 Succ 3P AR(1452)
Fig 18
DDB: Seq Counter=1(847)
&
CB2 SUCCESSFUL 3 PAR SHOT1 COUNTER
Fig 18
DDB: Seq Counter=2(848)
CB2 SUCCESSFUL 3 PAR SHOT2 COUNTER
Fig 18
DDB: Seq Counter=3(849)
CB2 SUCCESSFUL 3 PAR SHOT3 COUNTER
Fig 18
DDB: Seq Counter=4(850)
CB2 SUCCESSFUL 3 PAR SHOT4 COUNTER
Fig 17
DDB: CB2 ARIP(1435)
0
0.02
Fig 56
DDB: CB2 AR Lockout(328)
CB2 FAILED AR COUNTER
DDB: Ext Rst CB2 Shots(1418)
1
COMMAND: Reset CB2shots Yes /No
Yes
P4137ENa

Figure AR 151 - CB2 AR shots counters

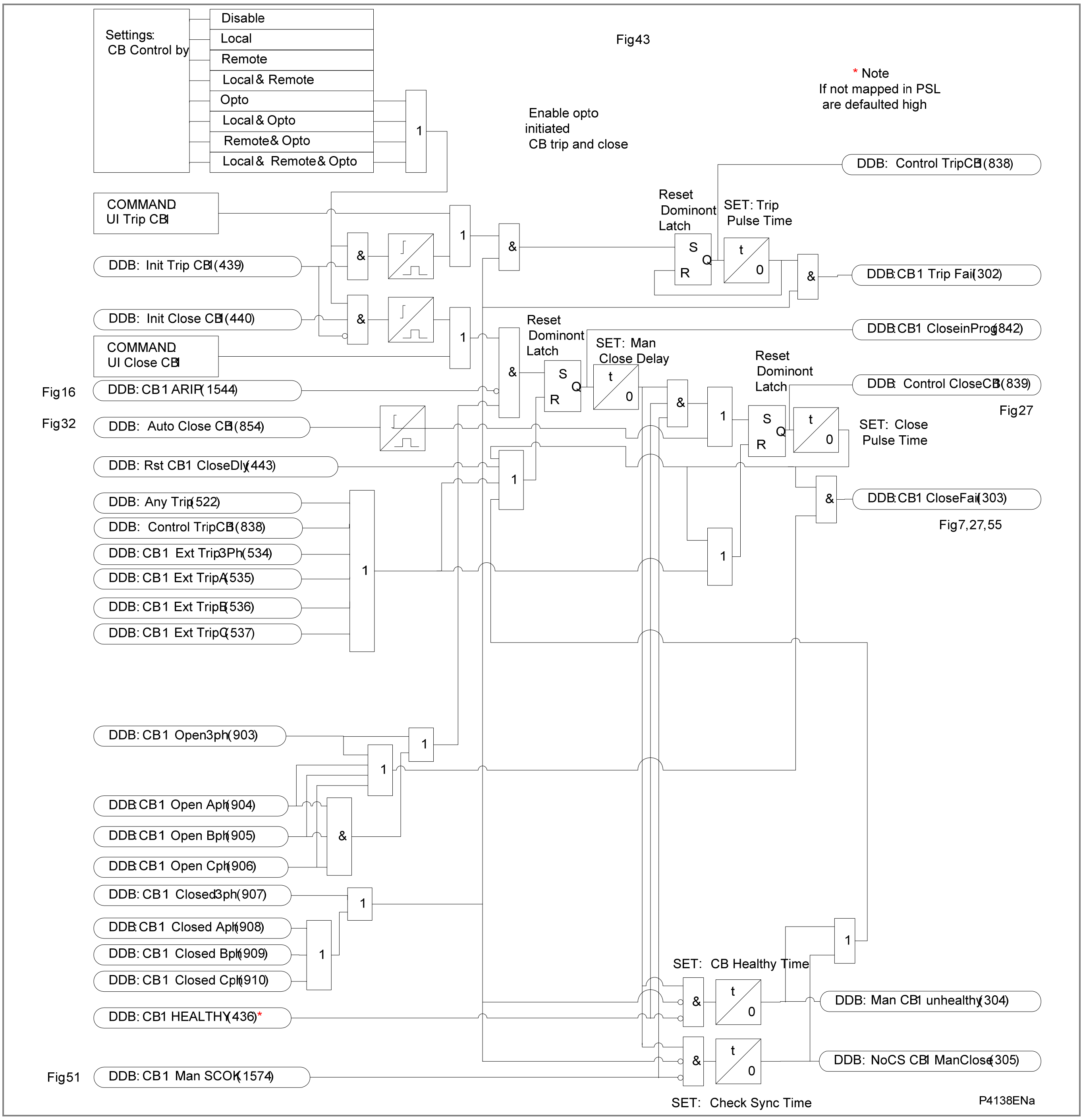

Settings:
CB Control by
Disable
Local
Remote
Local & Remote
Opto
Local & Opto
Remote & Opto
Local & Remote & Opto
1
Fig43
* Note
If not mapped in PSL
are defaulted high
Enable opto
initiated
CB trip and close
DDB: Control TripCB (838)
COMMAND
UI Trip CB1
Reset
Dominont
Latch
SET: Trip
Pulse Time
DDB: Init Trip CB1 (439)
&
1
&
S
Q
R
t
0
&
DDB:CB1 Trip Fail (302)
DDB: Init Close CB1 (440)
&
1
Reset
Dominont
Latch
DDB:CB1 CloseinProg (842)
COMMAND
UI Close CB1
SET: Man
Close Delay
Reset
Dominont
Latch
&
S
Q
R
t
0
DDB: Control CloseCB (839)
Fig16
DDB: CB1 ARIP (1544)
&
1
S
Q
R
t
0
Fig27
Fig32
DDB: Auto Close CB (854)
SET: Close
Pulse Time
DDB: Rst CB1 CloseDly (443)
1
DDB: Any Trip (522)
&
DDB:CB1 CloseFail (303)
DDB: Control TripCB (838)
Fig7,27,55
DDB: CB1 Ext Trip3Ph (534)
1
1
DDB: CB1 Ext TripA (535)
DDB: CB1 Ext TripB (536)
DDB: CB1 Ext TripC (537)
DDB: CB1 Open3ph (903)
1
1
DDB:CB1 Open Aph (904)
&
DDB:CB1 Open Bph (905)
DDB:CB1 Open Cph (906)
DDB: CB1 Closed3ph (907)
1
DDB:CB1 Closed Aph (908)
1
DDB: CB1 Closed Bph (909)
1
DDB: CB1 Closed Cph (910)
SET: CB Healthy Time
&
t
0
DDB: Man CB1 unhealthy (304)
DDB: CB1 HEALTHY (436)*
&
t
0
DDB: NoCS CB1 ManClose (305)
Fig51
DDB: CB1 Man SCOK (1574)
SET: Check Sync Time
P4138ENa

Figure AR 152 - CB1 circuit breaker control

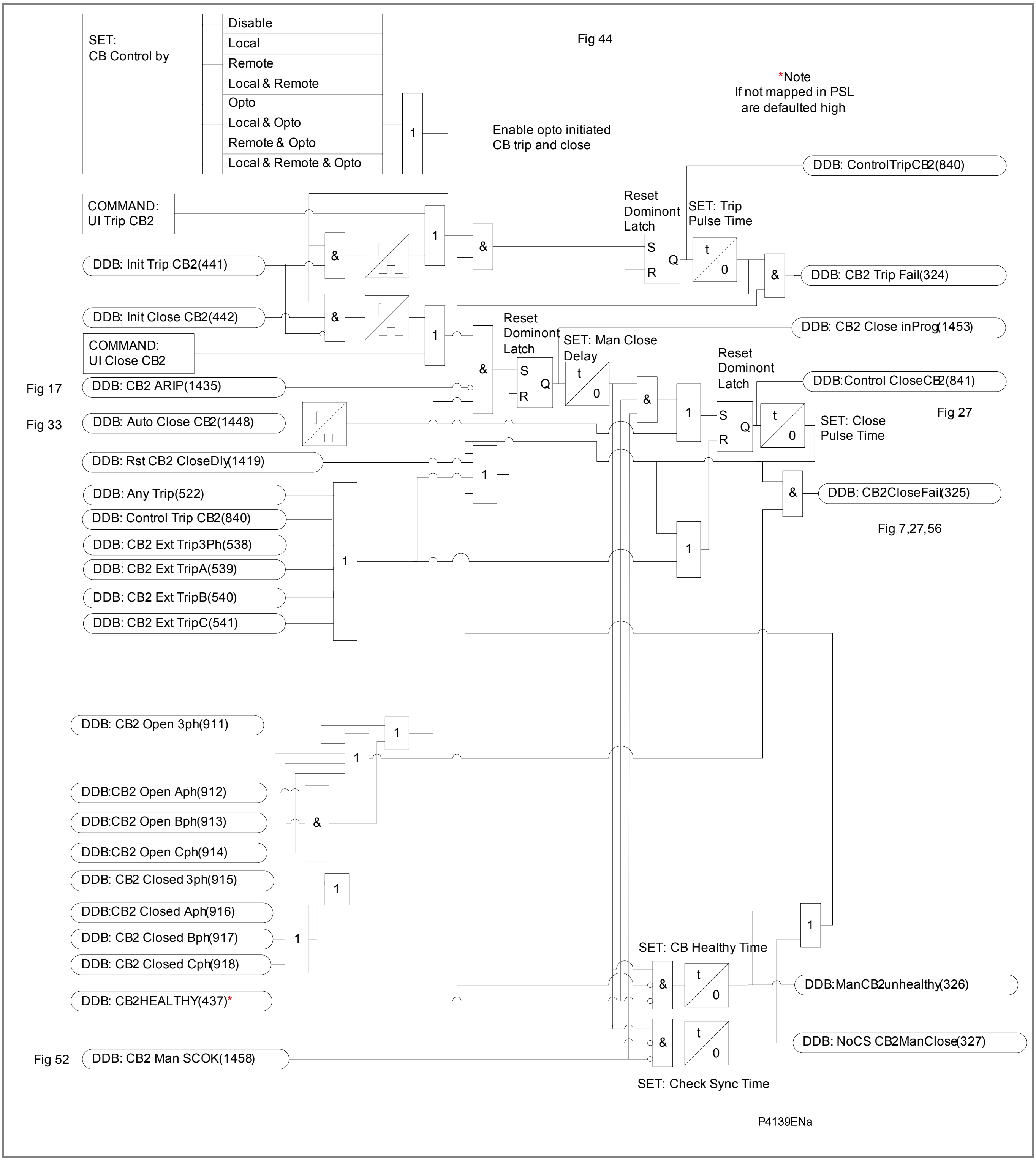

SET:
CB Control by
Disable
Local
Remote
Local & Remote
Opto
Local & Opto
Remote & Opto
Local & Remote & Opto
Fig 44
*Note
If not mapped in PSL
are defaulted high
Enable opto initiated
CB trip and close
DDB: ControlTripCB2(840)
COMMAND:
UI Trip CB2
Reset
Dominont
Latch
SET: Trip
Pulse Time
DDB: Init Trip CB2(441)
DDB: CB2 Trip Fail(324)
DDB: Init Close CB2(442)
DDB: CB2 Close inProg(1453)
COMMAND:
UI Close CB2
Reset
Dominont
Latch
SET: Man Close
Delay
Reset
Dominont
Latch
DDB:Control CloseCB2(841)
Fig 17
DDB: CB2 ARIP(1435)
Fig 33
DDB: Auto Close CB2(1448)
SET: Close
Pulse Time
Fig 27
DDB: Rst CB2 CloseDly(1419)
DDB: Any Trip(522)
DDB: CB2CloseFail(325)
DDB: Control Trip CB2(840)
Fig 7,27,56
DDB: CB2 Ext Trip3Ph(538)
DDB: CB2 Ext TripA(539)
DDB: CB2 Ext TripB(540)
DDB: CB2 Ext TripC(541)
DDB: CB2 Open 3ph(911)
DDB:CB2 Open Aph(912)
DDB:CB2 Open Bph(913)
DDB:CB2 Open Cph(914)
DDB: CB2 Closed 3ph(915)
DDB:CB2 Closed Aph(916)
DDB: CB2 Closed Bph(917)
DDB: CB2 Closed Cph(918)
SET: CB Healthy Time
DDB:ManCB2unhealthy(326)
DDB: CB2HEALTHY(437)*
Fig 52
DDB: CB2 Man SCOK(1458)
DDB: NoCS CB2ManClose(327)
SET: Check Sync Time
P4139ENa

Figure AR 153 - CB2 circuit breaker control

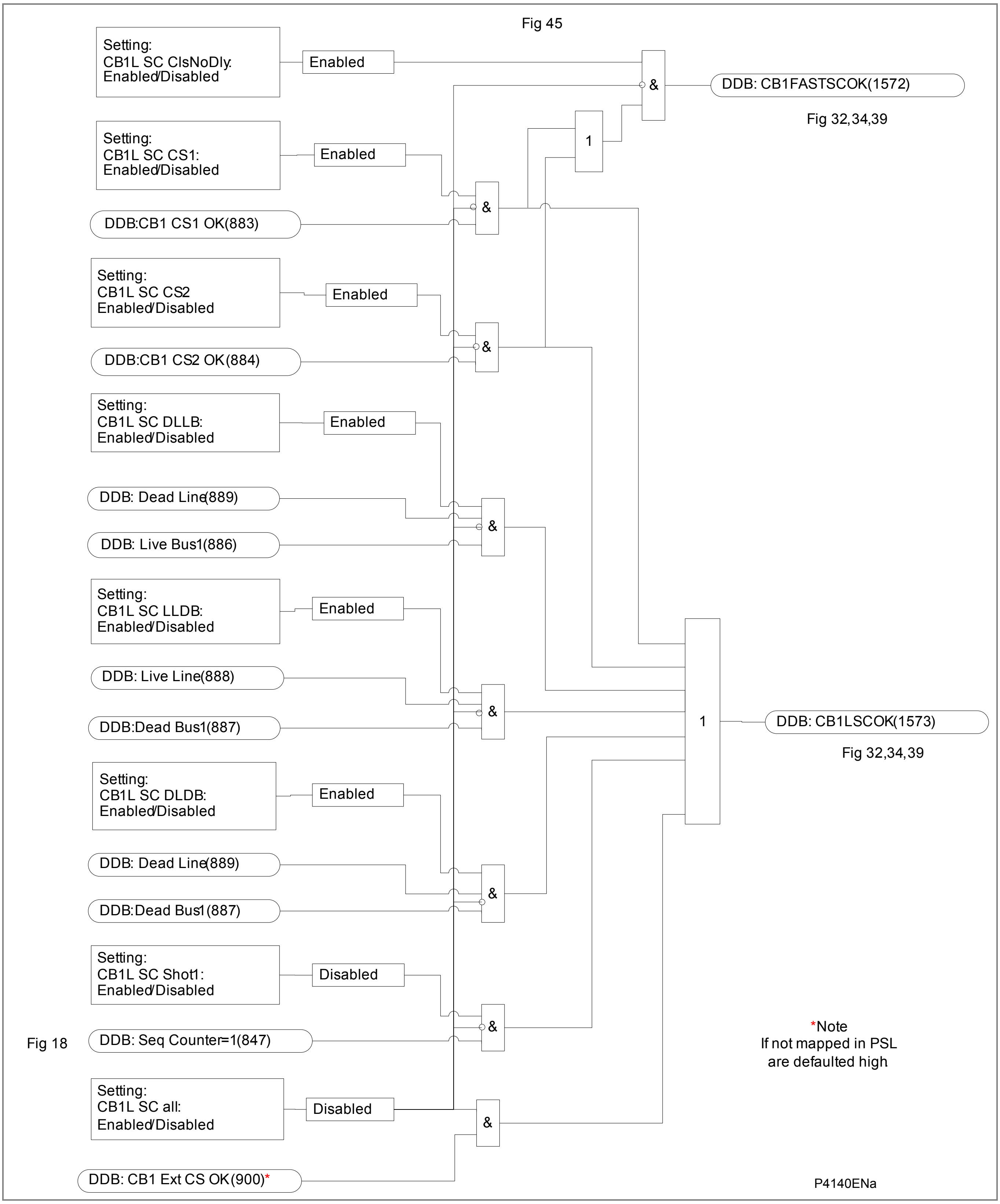


Fig 45
Setting:
CB1L SC ClsNoDly:
Enabled/Disabled
Enabled
&
DDB: CB1FASTSCOK(1572)
Fig 32,34,39
Setting:
CB1L SC CS1:
Enabled/Disabled
Enabled
1
&
DDB:CB1 CS1 OK(883)
Setting:
CB1L SC CS2
Enabled/Disabled
Enabled
&
DDB:CB1 CS2 OK(884)
Setting:
CB1L SC DLLB:
Enabled/Disabled
Enabled
DDB: Dead Line(889)
&
DDB: Live Bus1(886)
Setting:
CB1L SC LLDB:
Enabled/Disabled
Enabled
DDB: Live Line(888)
&
DDB:Dead Bus1(887)
1
DDB: CB1LSCOK(1573)
Fig 32,34,39
Setting:
CB1L SC DLDB:
Enabled/Disabled
Enabled
DDB: Dead Line(889)
&
DDB:Dead Bus1(887)
Setting:
CB1L SC Shot1:
Enabled/Disabled
Disabled
&
Fig 18
DDB: Seq Counter=1(847)
*Note
If not mapped in PSL
are defaulted high
Setting:
CB1L SC all:
Enabled/Disabled
Disabled
&
DDB: CB1 Ext CS OK(900)*
P4140ENa

Figure AR 154 - CB1 lead 3PAR system check

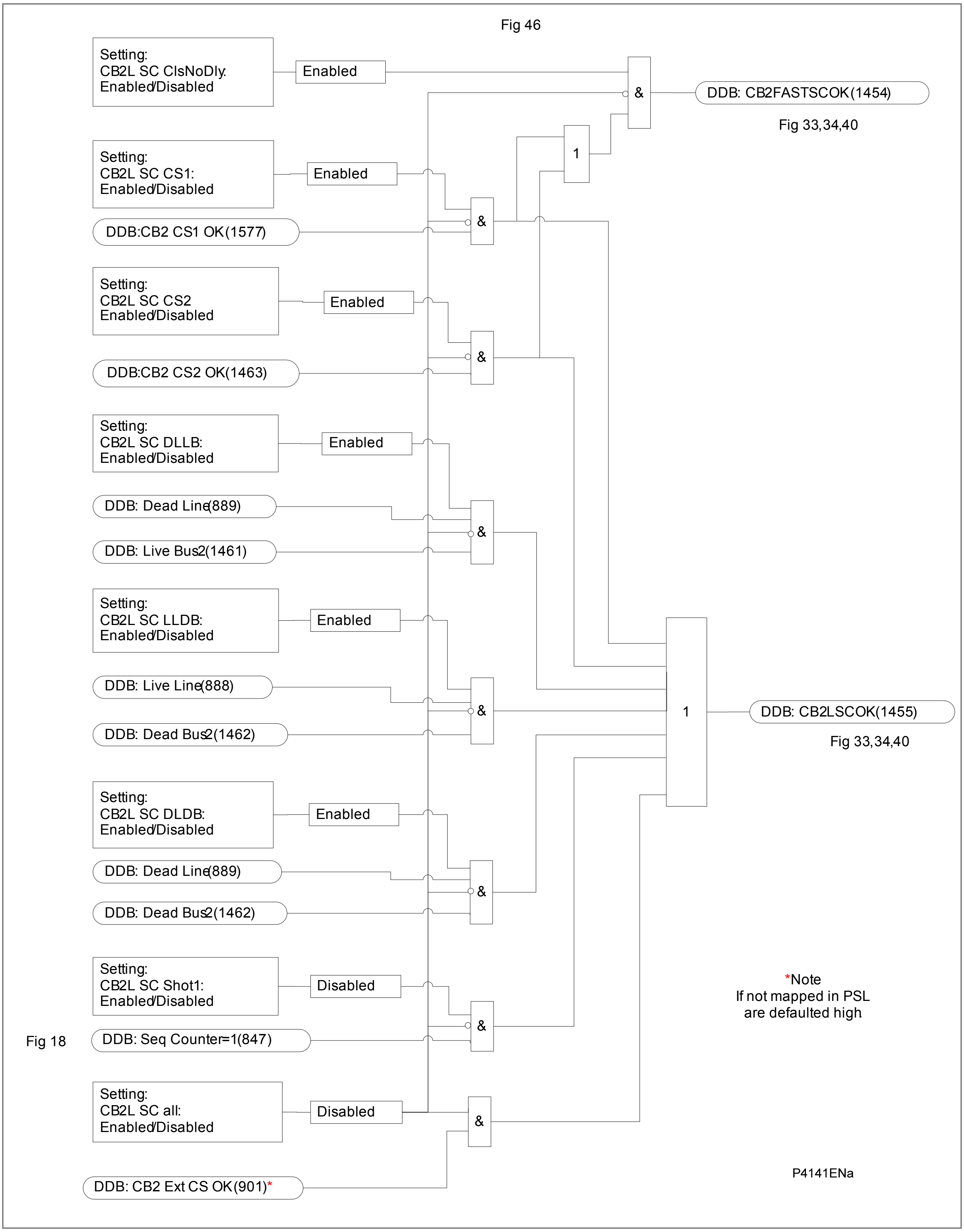


Fig 46
Setting:
CB2L SC ClsNoDly.
Enabled/Disabled
Enabled
&
DDB: CB2FASTSCOK(1454)
Fig 33,34,40
1
Setting:
CB2L SC CS1:
Enabled/Disabled
Enabled
&
DDB:CB2 CS1 OK(1577)
Setting:
CB2L SC CS2
Enabled/Disabled
Enabled
&
DDB:CB2 CS2 OK(1463)
Setting:
CB2L SC DLLB:
Enabled/Disabled
Enabled
DDB: Dead Line(889)
&
DDB: Live Bus2(1461)
Setting:
CB2L SC LLDB:
Enabled/Disabled
Enabled
DDB: Live Line(888)
&
1
DDB: CB2LSCOK(1455)
DDB: Dead Bus2(1462)
Fig 33,34,40
Setting:
CB2L SC DLDB:
Enabled/Disabled
Enabled
DDB: Dead Line(889)
&
DDB: Dead Bus2(1462)
Setting:
CB2L SC Shot1:
Enabled/Disabled
Disabled
*Note
If not mapped in PSL
are defaulted high
&
Fig 18
DDB: Seq Counter=1(847)
Setting:
CB2L SC all:
Enabled/Disabled
Disabled
&
P4141ENa
DDB: CB2 Ext CS OK(901)*

Figure AR 155 - CB2 lead 3PAR system check

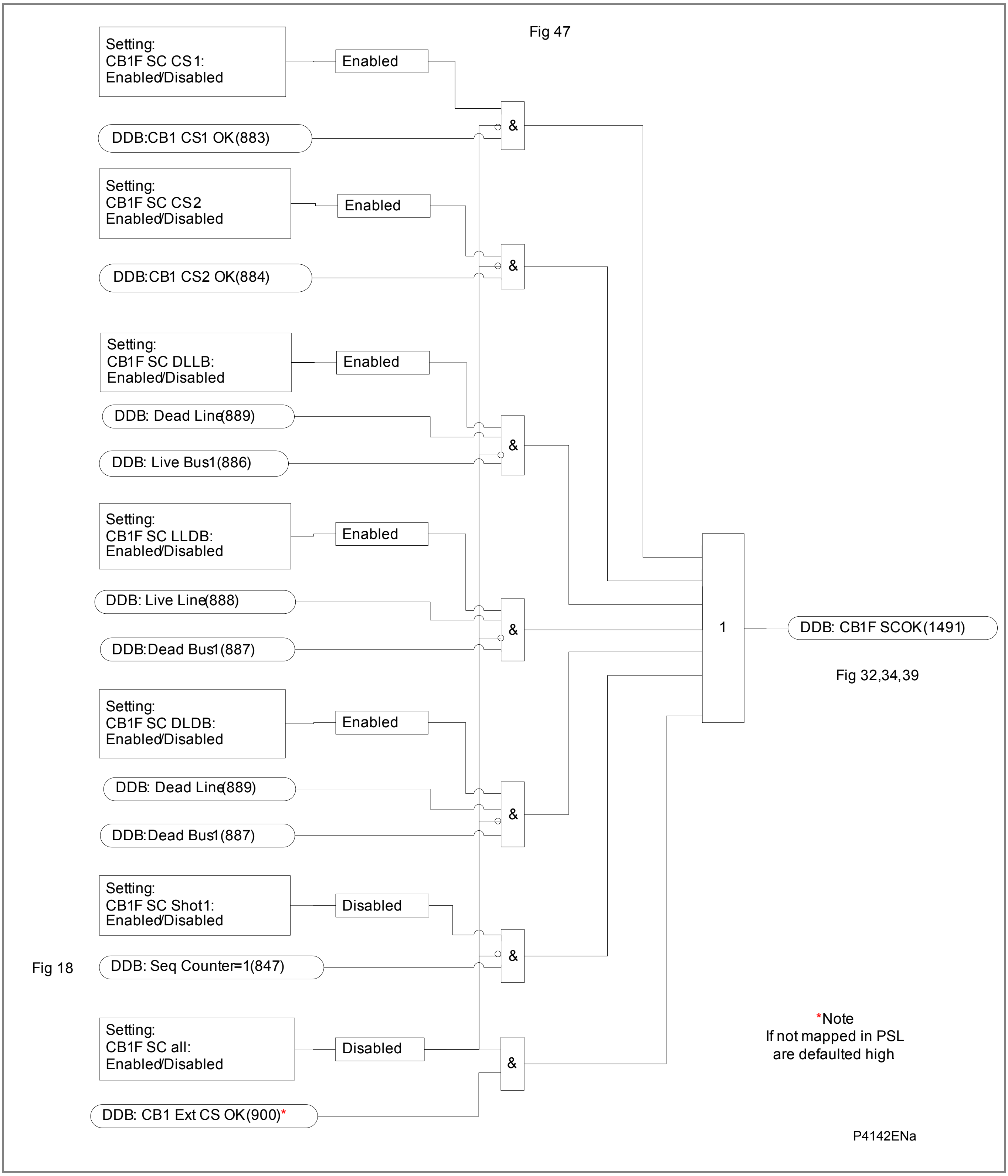


Fig 47
Setting:
CB1F SC CS1:
Enabled/Disabled
Enabled
&
DDB:CB1 CS1 OK(883)
Setting:
CB1F SC CS2
Enabled/Disabled
Enabled
&
DDB:CB1 CS2 OK(884)
Setting:
CB1F SC DLLB:
Enabled/Disabled
Enabled
DDB: Dead Line(889)
&
DDB: Live Bus1(886)
Setting:
CB1F SC LLDB:
Enabled/Disabled
Enabled
DDB: Live Line(888)
&
DDB:Dead Bus1(887)
1
DDB: CB1F SCOK(1491)
Fig 32,34,39
Setting:
CB1F SC DLDB:
Enabled/Disabled
Enabled
DDB: Dead Line(889)
&
DDB:Dead Bus1(887)
Setting:
CB1F SC Shot1:
Enabled/Disabled
Disabled
&
Fig 18
DDB: Seq Counter=1(847)
Setting:
CB1F SC all:
Enabled/Disabled
Disabled
&
DDB: CB1 Ext CS OK(900)*
*Note
If not mapped in PSL
are defaulted high
P4142ENa

Figure AR 156 - CB1 follow 3PAR system check

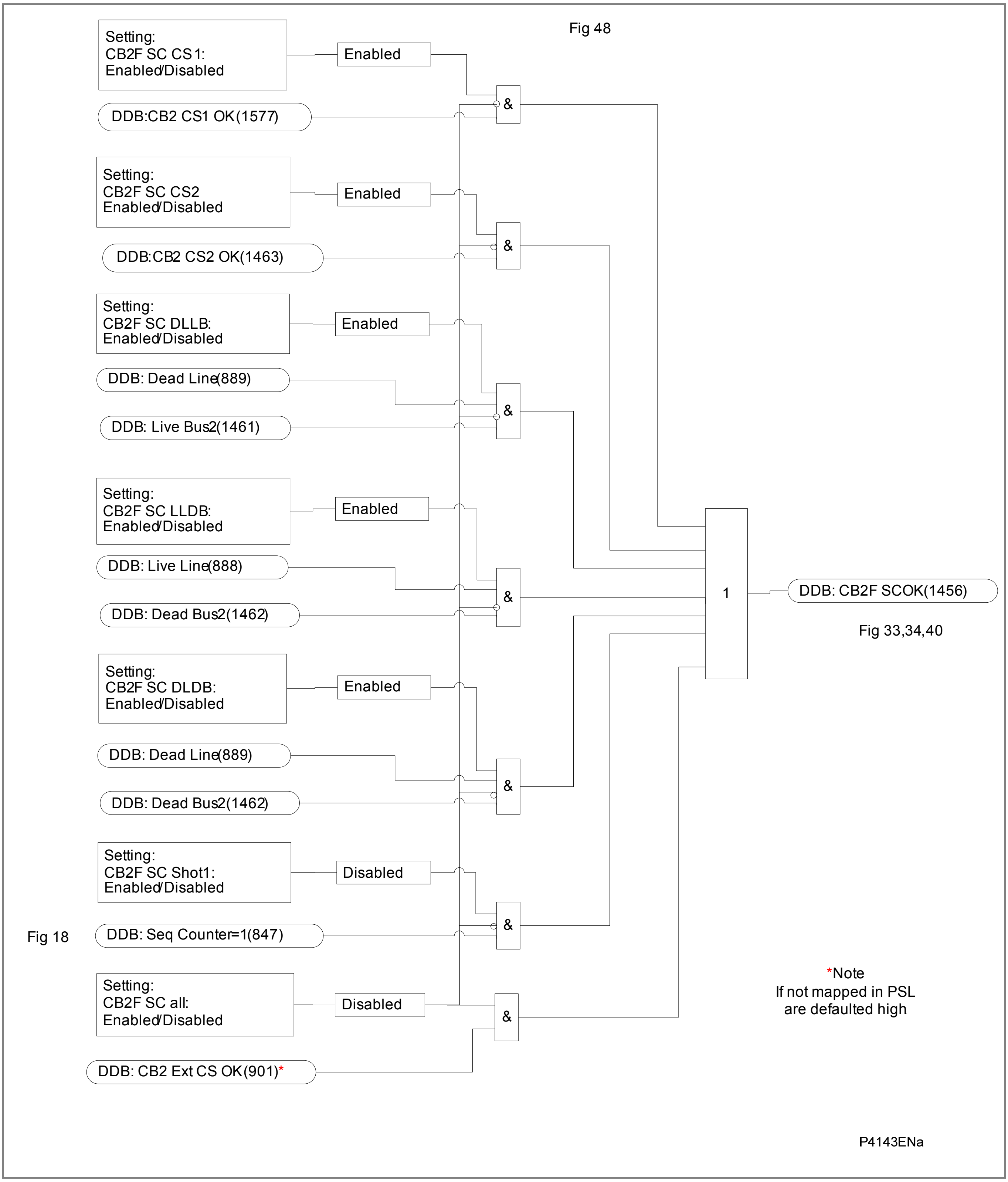


Fig 48
Setting: CB2F SC CS1: Enabled/Disabled
Enabled
DDB:CB2 CS1 OK(1577)
Setting: CB2F SC CS2 Enabled/Disabled
Enabled
DDB:CB2 CS2 OK(1463)
Setting: CB2F SC DLLB: Enabled/Disabled
Enabled
DDB: Dead Line(889)
DDB: Live Bus2(1461)
Setting: CB2F SC LLDB: Enabled/Disabled
Enabled
DDB: Live Line(888)
DDB: Dead Bus2(1462)
Setting: CB2F SC DLDB: Enabled/Disabled
Enabled
DDB: Dead Line(889)
DDB: Dead Bus2(1462)
Setting: CB2F SC Shot1: Enabled/Disabled
Disabled
Fig 18
DDB: Seq Counter=1(847)
Setting: CB2F SC all: Enabled/Disabled
Disabled
DDB: CB2 Ext CS OK(901)*
&
&
&
&
&
&
&
1
DDB: CB2F SCOK(1456)
Fig 33,34,40
*Note
If not mapped in PSL are defaulted high
P4143ENa

Figure AR 157 - CB2 follow 3PAR system check

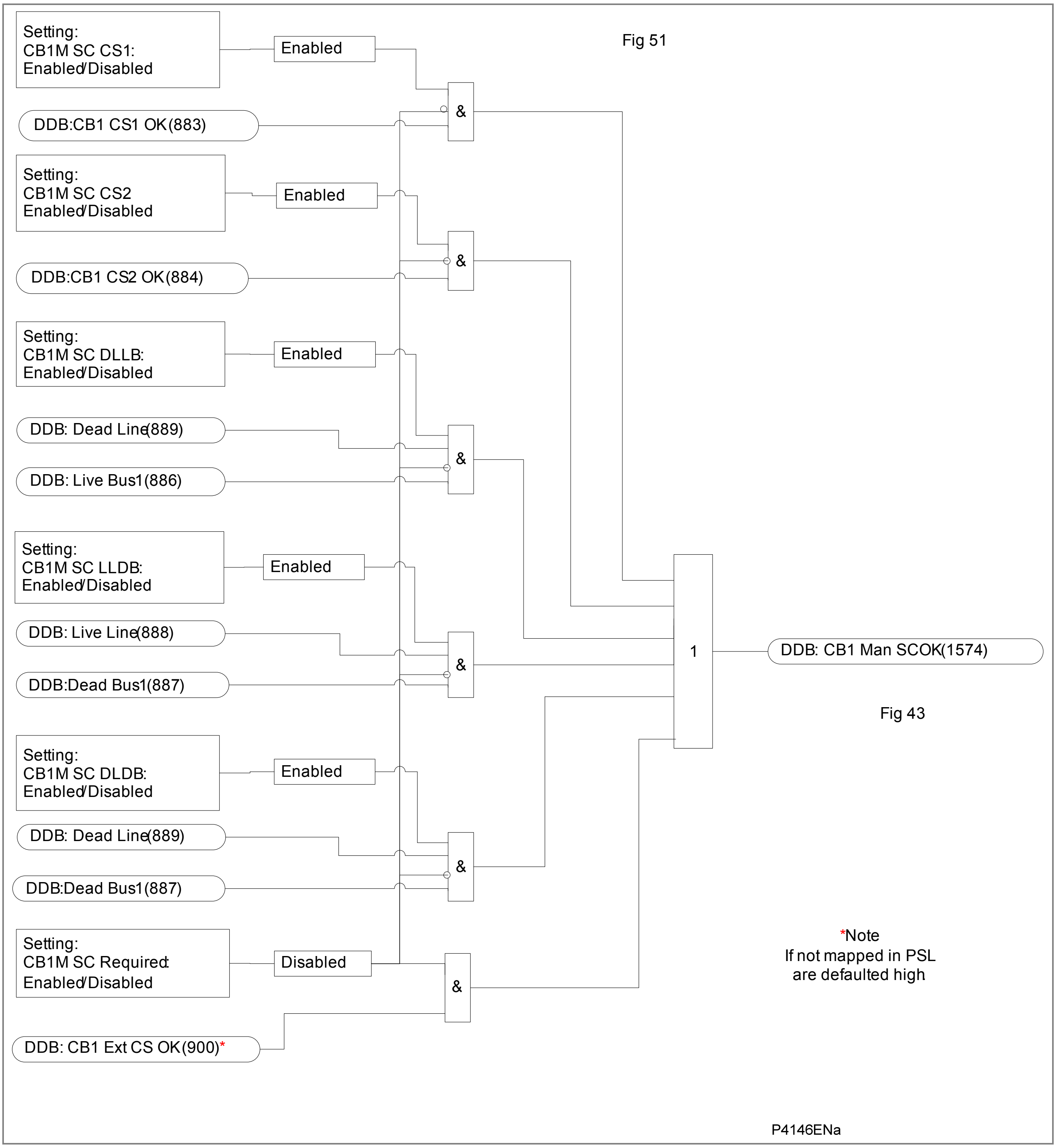

Setting:
CB1M SC CS1:
Enabled/Disabled
Enabled
DDB:CB1 CS1 OK(883)
Setting:
CB1M SC CS2
Enabled/Disabled
Enabled
DDB:CB1 CS2 OK(884)
Setting:
CB1M SC DLLB:
Enabled/Disabled
Enabled
DDB: Dead Line(889)
DDB: Live Bus1(886)
Setting:
CB1M SC LLDB:
Enabled/Disabled
Enabled
DDB: Live Line(888)
DDB:Dead Bus1(887)
Setting:
CB1M SC DLDB:
Enabled/Disabled
Enabled
DDB: Dead Line(889)
DDB:Dead Bus1(887)
Setting:
CB1M SC Required:
Enabled/Disabled
Disabled
DDB: CB1 Ext CS OK(900)*
&
&
&
&
&
&
1
DDB: CB1 Man SCOK(1574)
Fig 51
Fig 43
*Note
If not mapped in PSL
are defaulted high
P4146ENa

Figure AR 158 - CB1 man. close system check

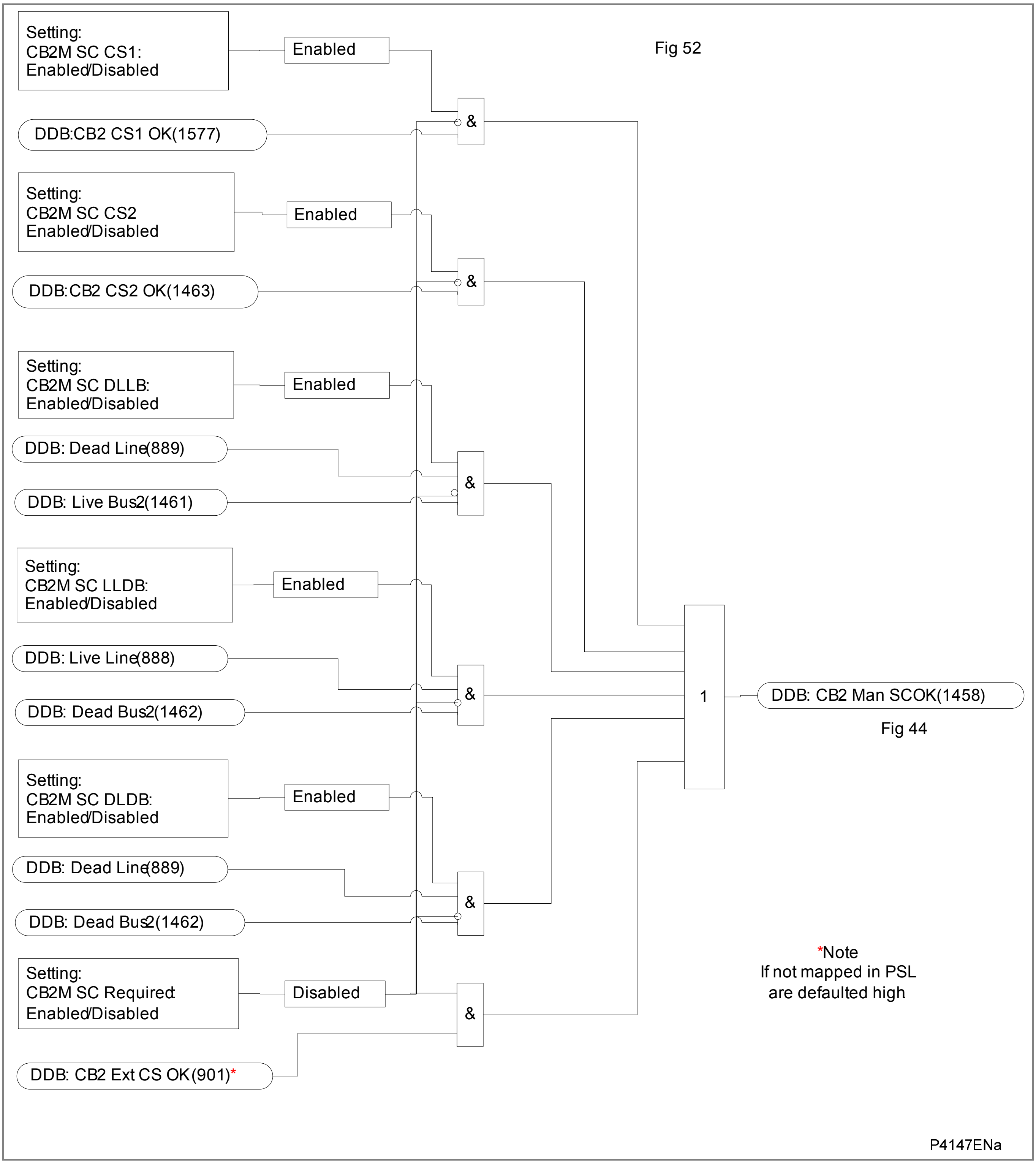

Setting:
CB2M SC CS1:
Enabled/Disabled
Enabled
DDB:CB2 CS1 OK(1577)
Setting:
CB2M SC CS2
Enabled/Disabled
Enabled
DDB:CB2 CS2 OK(1463)
Setting:
CB2M SC DLLB:
Enabled/Disabled
Enabled
DDB: Dead Line(889)
DDB: Live Bus2(1461)
Setting:
CB2M SC LLDB:
Enabled/Disabled
Enabled
DDB: Live Line(888)
DDB: Dead Bus2(1462)
Setting:
CB2M SC DLDB:
Enabled/Disabled
Enabled
DDB: Dead Line(889)
DDB: Dead Bus2(1462)
Setting:
CB2M SC Required:
Enabled/Disabled
Disabled
DDB: CB2 Ext CS OK(901)*
&
&
&
&
&
&
Fig 52
1
DDB: CB2 Man SCOK(1458)
Fig 44
*Note
If not mapped in PSL
are defaulted high
P4147ENa

Figure AR 159 - CB2 man. close system check

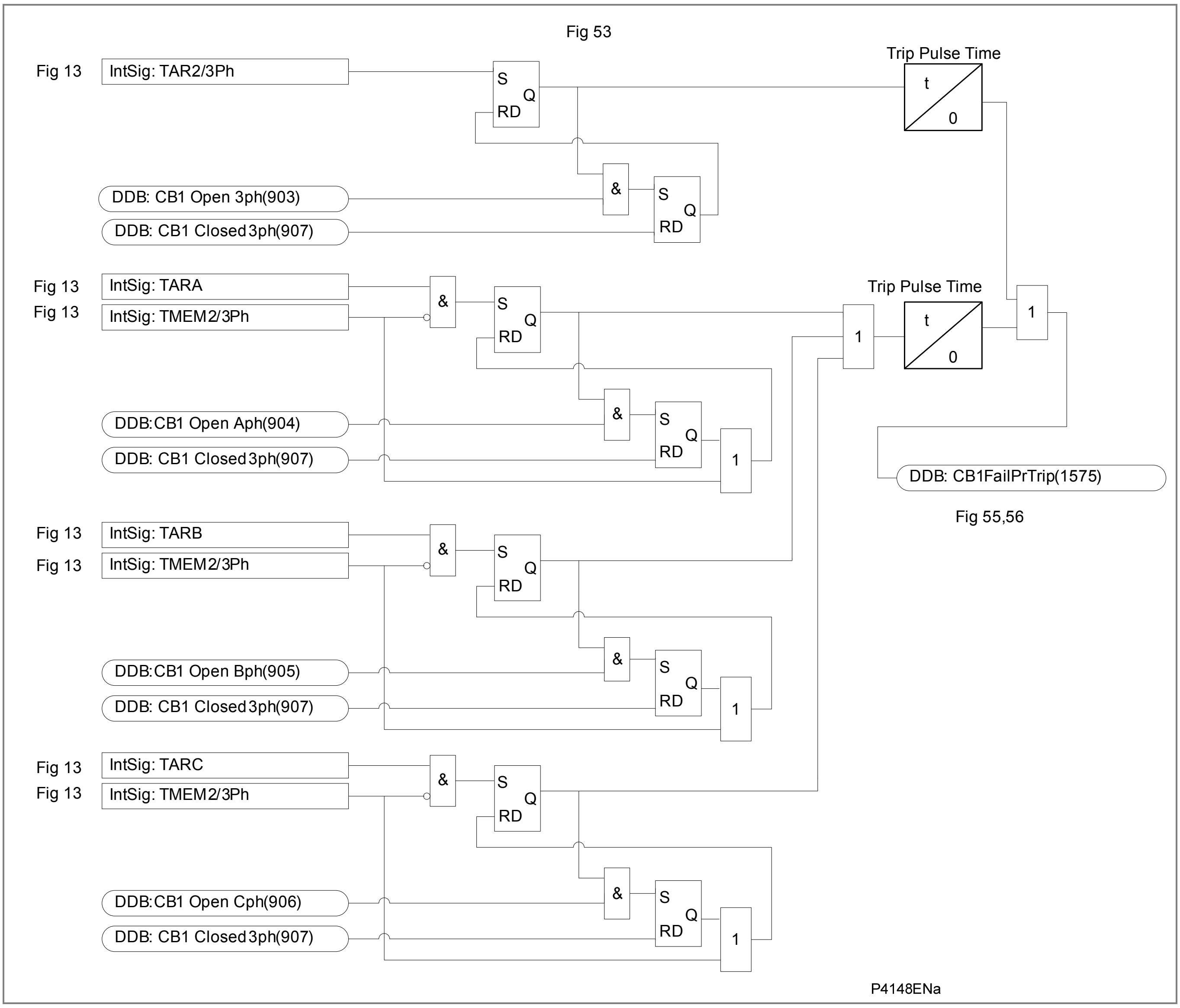


Fig 53
Trip Pulse Time
t
0
Fig 13
IntSig: TAR2/3Ph
S
Q
RD
&
DDB: CB1 Open 3ph(903)
DDB: CB1 Closed 3ph(907)
Fig 13
IntSig: TARA
Fig 13
IntSig: TMEM2/3Ph
Trip Pulse Time
1
DDB:CB1 Open Aph(904)
DDB: CB1 Closed 3ph(907)
DDB: CB1FailPrTrip(1575)
Fig 55,56
Fig 13
IntSig: TARB
Fig 13
IntSig: TMEM2/3Ph
DDB:CB1 Open Bph(905)
DDB: CB1 Closed 3ph(907)
Fig 13
IntSig: TARC
Fig 13
IntSig: TMEM2/3Ph
DDB:CB1 Open Cph(906)
DDB: CB1 Closed 3ph(907)
P4148ENa

Figure AR 160 - CB1 trip time monitor

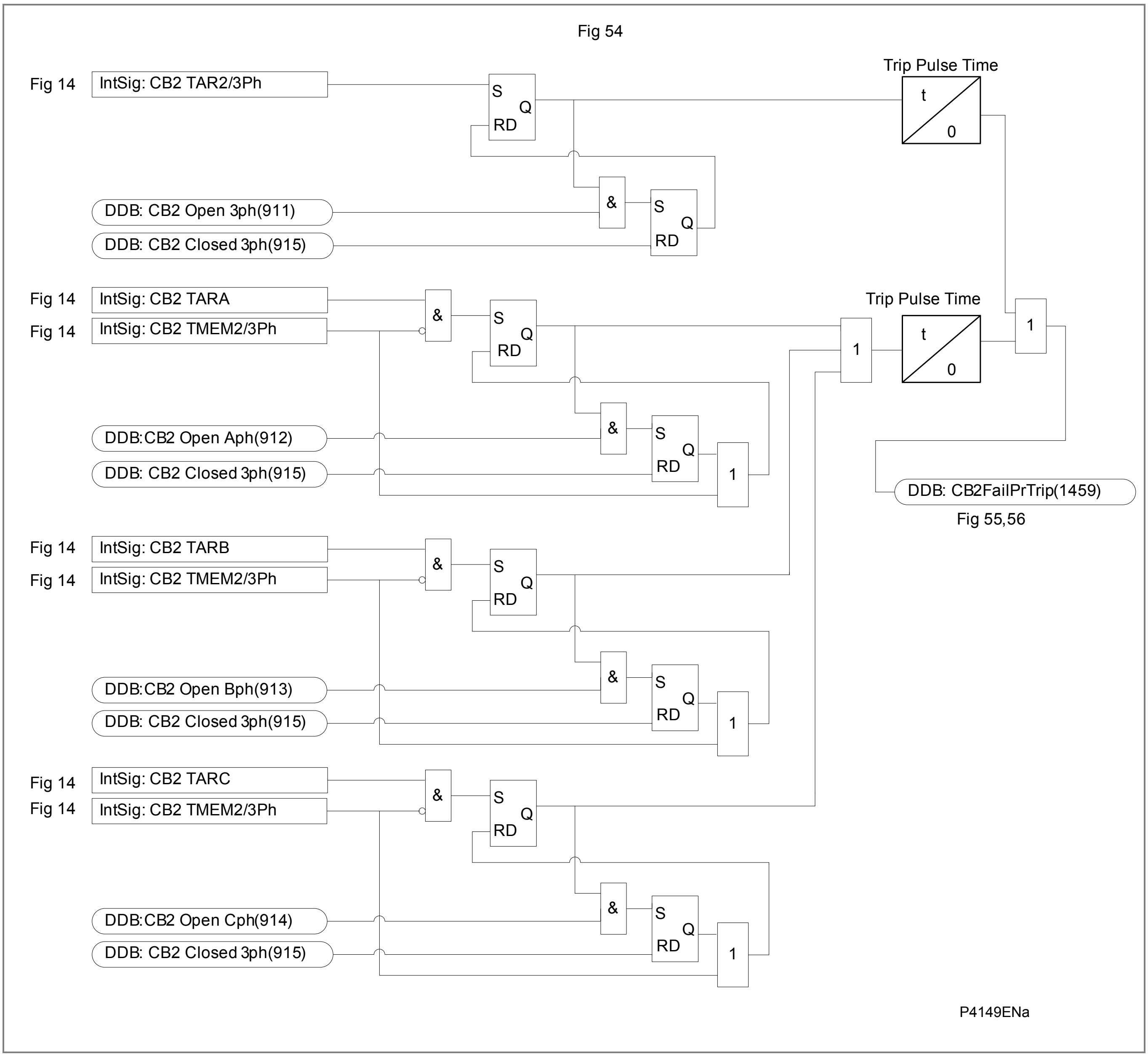


Fig 54
Trip Pulse Time
Fig 14
IntSig: CB2 TAR2/3Ph
S
Q
RD
t
0
&
DDB: CB2 Open 3ph(911)
DDB: CB2 Closed 3ph(915)
Fig 14
IntSig: CB2 TARA
Fig 14
IntSig: CB2 TMEM2/3Ph
Trip Pulse Time
1
DDB:CB2 Open Aph(912)
DDB: CB2 Closed 3ph(915)
DDB: CB2FailPrTrip(1459)
Fig 55,56
Fig 14
IntSig: CB2 TARB
Fig 14
IntSig: CB2 TMEM2/3Ph
DDB:CB2 Open Bph(913)
DDB: CB2 Closed 3ph(915)
Fig 14
IntSig: CB2 TARC
Fig 14
IntSig: CB2 TMEM2/3Ph
DDB:CB2 Open Cph(914)
DDB: CB2 Closed 3ph(915)
P4149ENa

Figure AR 161 - CB2 trip time monitor

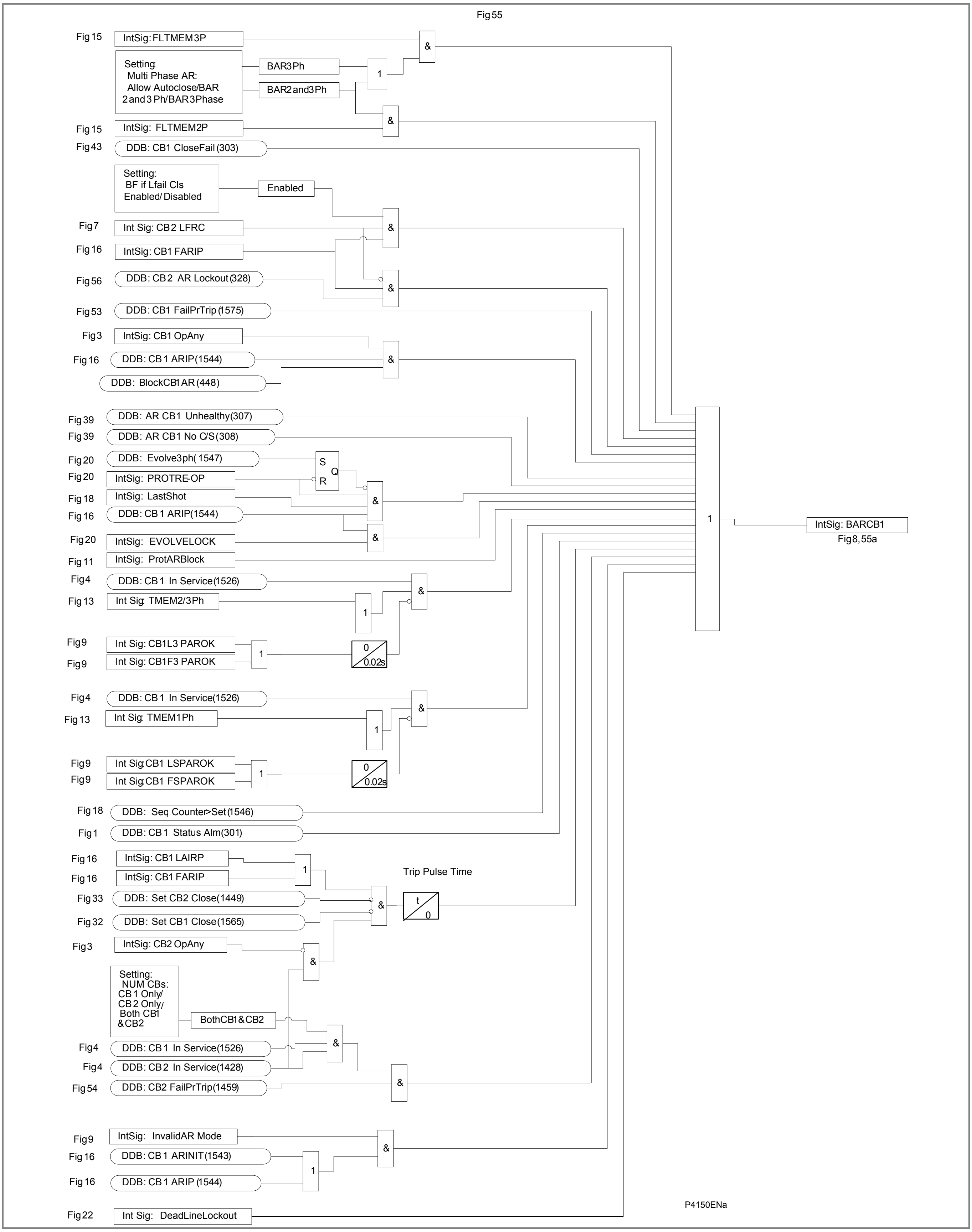


Fig55
Fig15
IntSig: FLTMEM3P
&
Setting:
Multi Phase AR:
Allow Autoclose/BAR
2and3 Ph/BAR3Phase
BAR3Ph
BAR2and3Ph
1
&
Fig15
IntSig: FLTMEM2P
Fig43
DDB: CB1 CloseFail (303)
Setting:
BF if Lfail Cls
Enabled/ Disabled
Enabled
Fig7
Int Sig: CB2 LFRC
&
Fig16
IntSig: CB1 FARIP
Fig56
DDB: CB2 AR Lockout(328)
&
Fig53
DDB: CB1 FailPrTrip(1575)
Fig3
IntSig: CB1 OpAny
Fig16
DDB: CB1 ARIP(1544)
&
DDB: BlockCB1AR (448)
Fig39
DDB: AR CB1 Unhealthy(307)
Fig39
DDB: AR CB1 No C/S(308)
Fig20
DDB: Evolve3ph(1547)
S
Q
R
Fig20
IntSig: PROTRE-OP
Fig18
IntSig: LastShot
&
Fig16
DDB: CB1 ARIP(1544)
&
Fig20
IntSig: EVOLVELOCK
Fig11
IntSig: ProtARBlock
1
IntSig: BARCB1
Fig8, 55a
Fig4
DDB: CB1 In Service(1526)
&
Fig13
Int Sig: TMEM2/3Ph
1
Fig9
Int Sig: CB1L3 PAROK
Fig9
Int Sig: CB1F3 PAROK
1
0
0.02s
Fig4
DDB: CB1 In Service(1526)
&
Fig13
Int Sig: TMEM1Ph
1
Fig9
Int Sig:CB1 LSPAROK
Fig9
Int Sig:CB1 FSPAROK
1
0
0.02s
Fig18
DDB: Seq Counter>Set(1546)
Fig1
DDB: CB1 Status Alm(301)
Fig16
IntSig: CB1 LAIRP
Fig16
IntSig: CB1 FARIP
1
Trip Pulse Time
Fig33
DDB: Set CB2 Close(1449)
&
t
0
Fig32
DDB: Set CB1 Close(1565)
Fig3
IntSig: CB2 OpAny
&
Setting:
NUM CBs:
CB1 Only/
CB2 Only/
Both CB1
&CB2
BothCB1&CB2
&
Fig4
DDB: CB1 In Service(1526)
Fig4
DDB: CB2 In Service(1428)
&
Fig54
DDB: CB2 FailPrTrip(1459)
Fig9
IntSig: InvalidAR Mode
&
Fig16
DDB: CB1 ARINIT(1543)
1
Fig16
DDB: CB1 ARIP (1544)
Fig22
Int Sig: DeadLineLockout
P4150ENa

Figure AR 162 - AR lockout - CB1

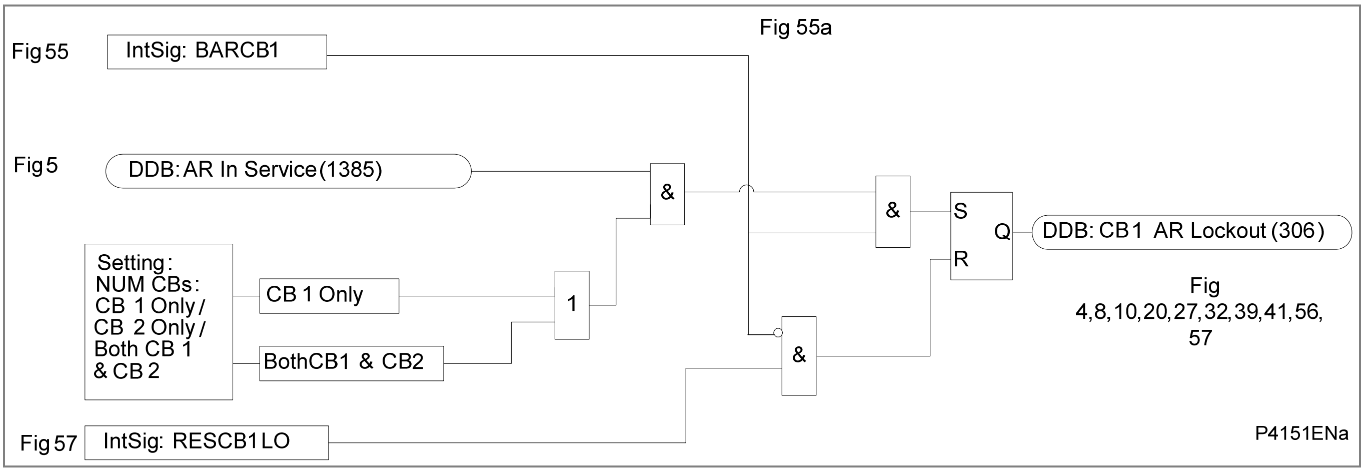


Fig 55a
Fig 55
IntSig: BARCB1
Fig 5
DDB: AR In Service (1385)
&
&
S
Q
R
DDB: CB1 AR Lockout (306)
Setting:
NUM CBs:
CB 1 Only /
CB 2 Only /
Both CB 1
& CB 2
CB 1 Only
BothCB1 & CB2
1
&
Fig
4,8,10,20,27,32,39,41,56,
57
Fig 57
IntSig: RESCB1LO
P4151ENa

Figure AR 163 - AR lockout - CB1

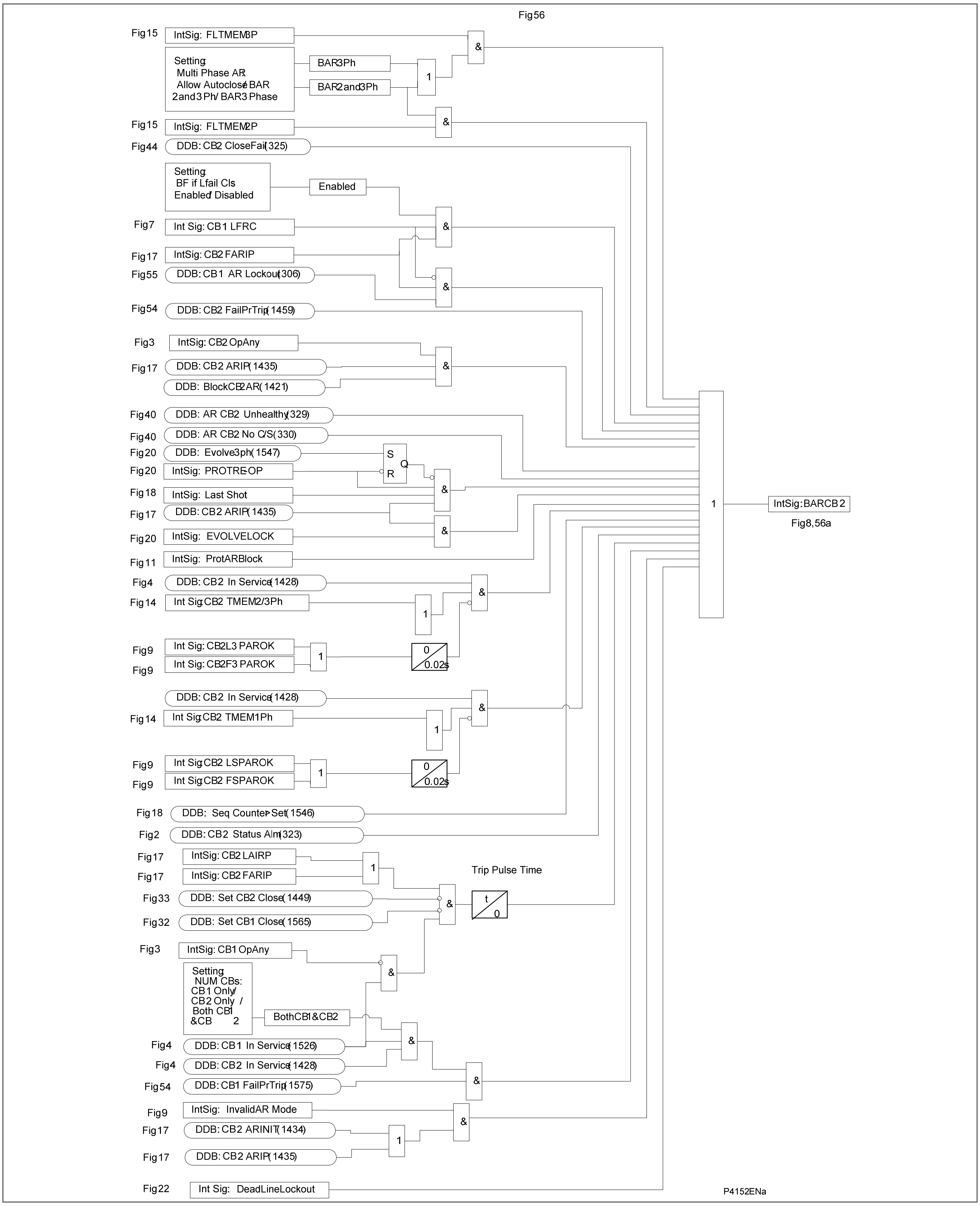


Fig56
Fig15 IntSig: FLTMEM3P
Setting: Multi Phase AR: Allow Autoclose BAR 2and3 Ph/ BAR3 Phase
BAR3Ph
BAR2and3Ph
Fig15 IntSig: FLTMEM2P
Fig44 DDB: CB2 CloseFail(325)
Setting: BF if Lfail Cls Enabled/ Disabled
Enabled
Fig7 Int Sig: CB1 LFRC
Fig17 IntSig: CB2 FARIP
Fig55 DDB: CB1 AR Lockout(306)
Fig54 DDB: CB2 FailPrTrip(1459)
Fig3 IntSig: CB2 OpAny
Fig17 DDB: CB2 ARIP(1435)
DDB: BlockCB2AR(1421)
Fig40 DDB: AR CB2 Unhealthy(329)
Fig40 DDB: AR CB2 No C/S(330)
Fig20 DDB: Evolve3ph(1547)
Fig20 IntSig: PROTRE-OP
S R Q
Fig18 IntSig: Last Shot
Fig17 DDB: CB2 ARIP(1435)
Fig20 IntSig: EVOLVELOCK
Fig11 IntSig: ProtARBlock
Fig4 DDB: CB2 In Service(1428)
Fig14 Int Sig:CB2 TMEM2/3Ph
Fig9 Int Sig: CB2L3 PAROK
Fig9 Int Sig: CB2F3 PAROK
0 0.02s
DDB: CB2 In Service(1428)
Fig14 Int Sig:CB2 TMEM1Ph
Fig9 Int Sig:CB2 LSPAROK
Fig9 Int Sig:CB2 FSPAROK
0 0.02s
Fig18 DDB: Seq Counter>Set(1546)
Fig2 DDB: CB2 Status Alm(323)
Fig17 IntSig: CB2 LAIRP
Fig17 IntSig: CB2 FARIP
Fig33 DDB: Set CB2 Close(1449)
Fig32 DDB: Set CB1 Close(1565)
Trip Pulse Time
t 0
Fig3 IntSig: CB1 OpAny
Setting: NUM CBs: CB1 Only/ CB2 Only / Both CB1 &CB 2
BothCB1&CB2
Fig4 DDB: CB1 In Service(1526)
Fig4 DDB: CB2 In Service(1428)
Fig54 DDB: CB1 FailPrTrip(1575)
Fig9 IntSig: InvalidAR Mode
Fig17 DDB: CB2 ARINIT(1434)
Fig17 DDB: CB2 ARIP(1435)
Fig22 Int Sig: DeadLineLockout
&
1
IntSig:BARCB2
Fig8,56a
P4152ENa

Figure AR 164 - AR lockout - CB2

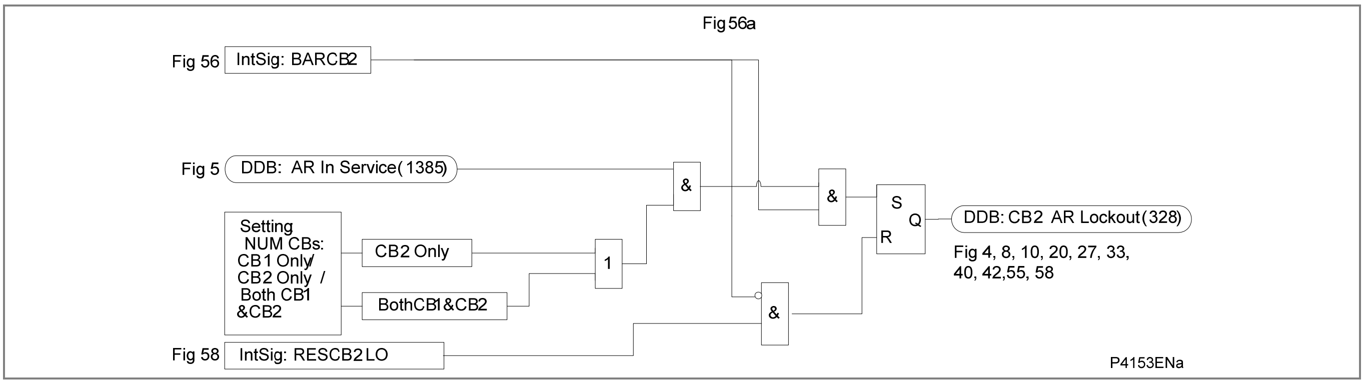


Fig 56a
Fig 56
IntSig: BARCB2
Fig 5
DDB: AR In Service (1385)
Setting
NUM CBs:
CB1 Only/
CB2 Only /
Both CB1
&CB2
CB2 Only
BothCB1&CB2
Fig 58
IntSig: RESCB2 LO
&
1
&
&
S
Q
R
DDB: CB2 AR Lockout (328)
Fig 4, 8, 10, 20, 27, 33,
40, 42,55, 58
P4153ENa

Figure AR 165 - AR lockout - CB2

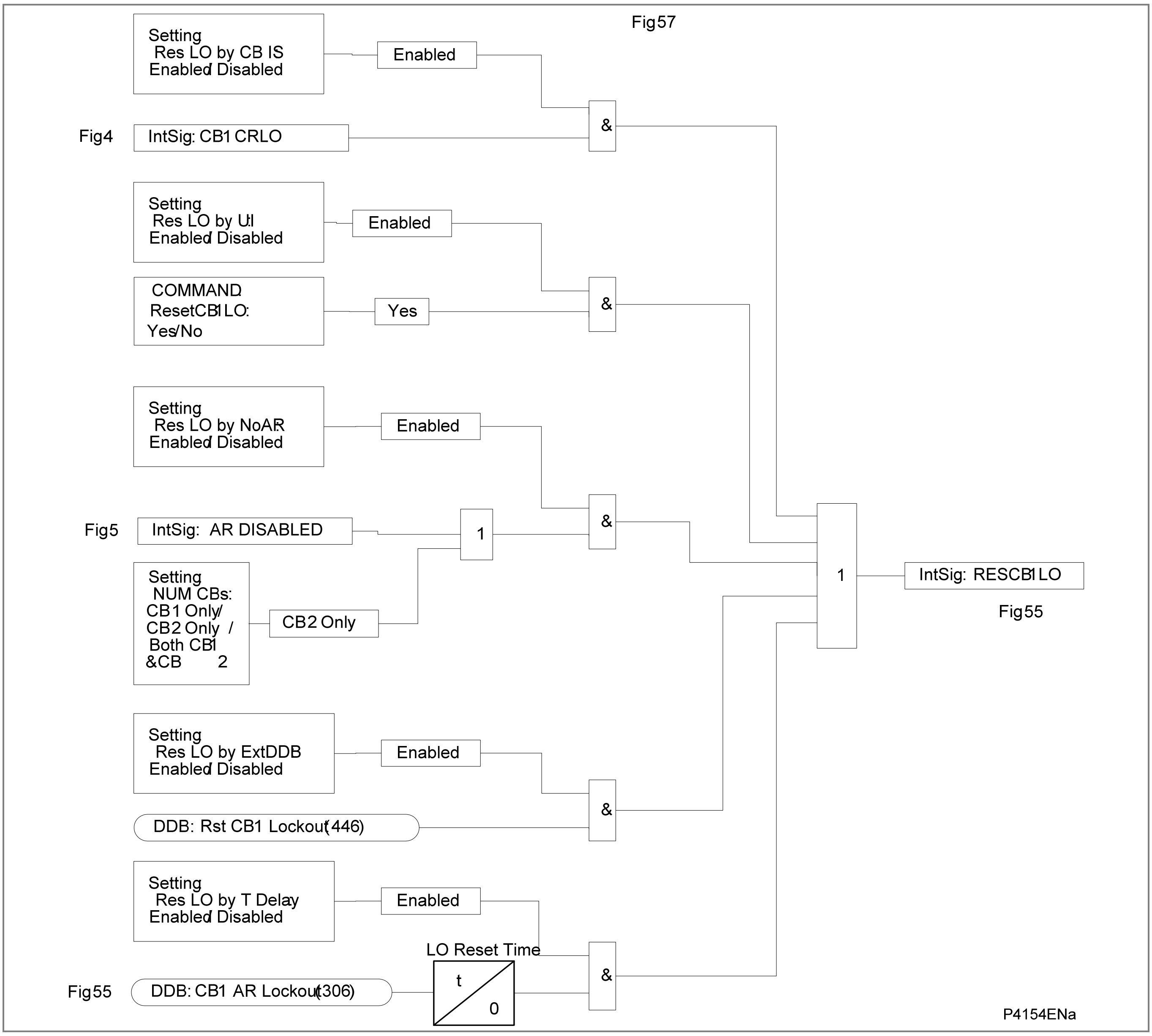


Fig57
Setting
Res LO by CB IS
Enabled/ Disabled
Enabled
Fig4
IntSig: CB1 CRLO
&
Setting
Res LO by UI
Enabled/ Disabled
Enabled
COMMAND
ResetCB1 LO:
Yes/No
Yes
&
Setting
Res LO by NoAR
Enabled/ Disabled
Enabled
&
Fig5
IntSig: AR DISABLED
1
Setting
NUM CBs:
CB1 Only/
CB2 Only /
Both CB1
&CB 2
CB2 Only
1
IntSig: RESCB1 LO
Fig55
Setting
Res LO by ExtDDB
Enabled/ Disabled
Enabled
&
DDB: Rst CB1 Lockout (446)
Setting
Res LO by T Delay
Enabled/ Disabled
Enabled
LO Reset Time
t
0
&
Fig55
DDB: CB1 AR Lockout (306)
P4154ENa

Figure AR 166 - Reset CB1 lockout

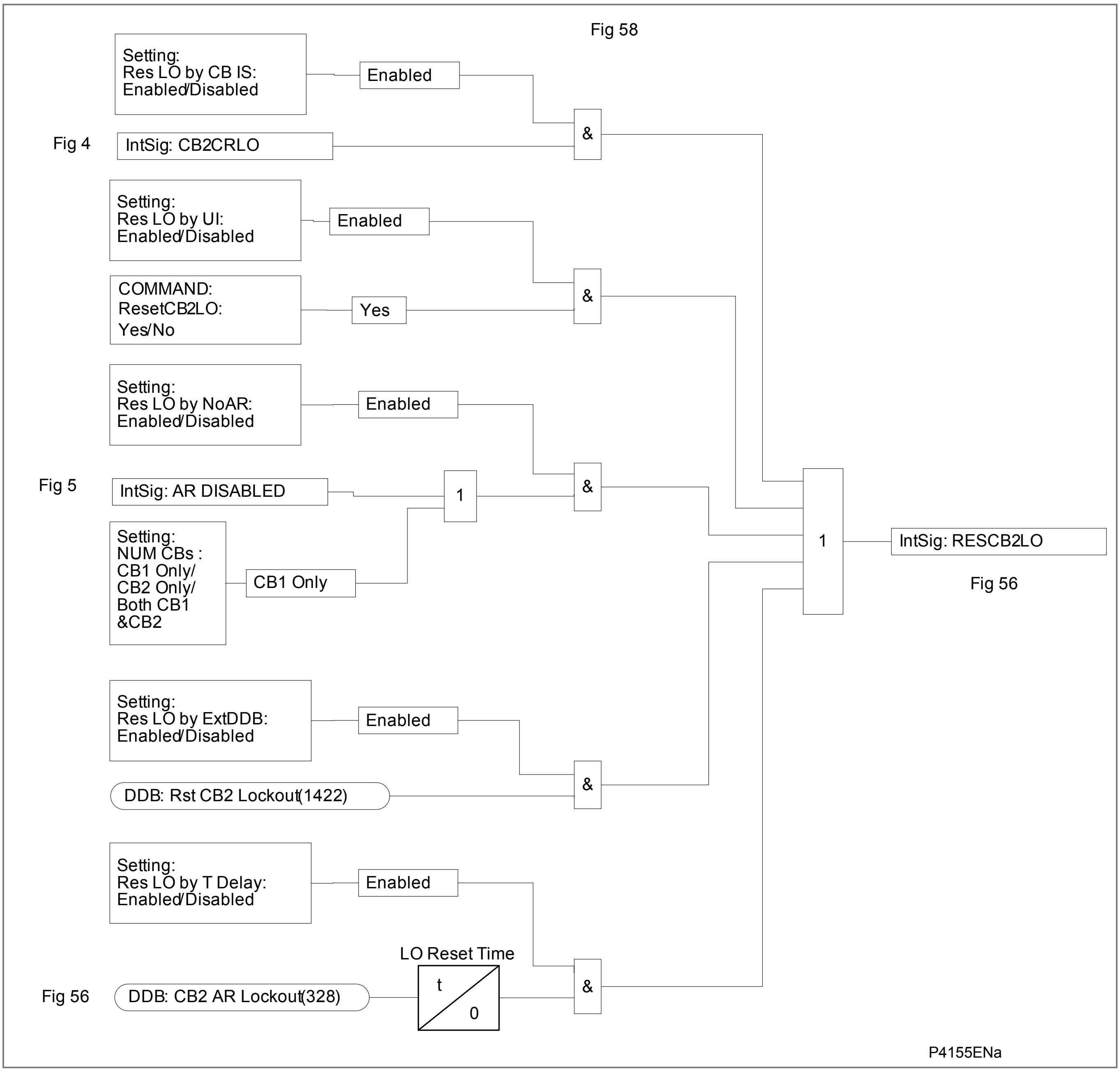


Fig 58
Setting:
Res LO by CB IS:
Enabled/Disabled
Enabled
Fig 4
IntSig: CB2CRLO
&
Setting:
Res LO by UI:
Enabled/Disabled
Enabled
COMMAND:
ResetCB2LO:
Yes/No
Yes
&
Setting:
Res LO by NoAR:
Enabled/Disabled
Enabled
Fig 5
IntSig: AR DISABLED
1
&
Setting:
NUM CBs :
CB1 Only/
CB2 Only/
Both CB1
&CB2
CB1 Only
1
IntSig: RESCB2LO
Fig 56
Setting:
Res LO by ExtDDB:
Enabled/Disabled
Enabled
DDB: Rst CB2 Lockout(1422)
&
Setting:
Res LO by T Delay:
Enabled/Disabled
Enabled
LO Reset Time
t
0
Fig 56
DDB: CB2 AR Lockout(328)
&
P4155ENa

Figure AR 167 - Reset CB2 lockout

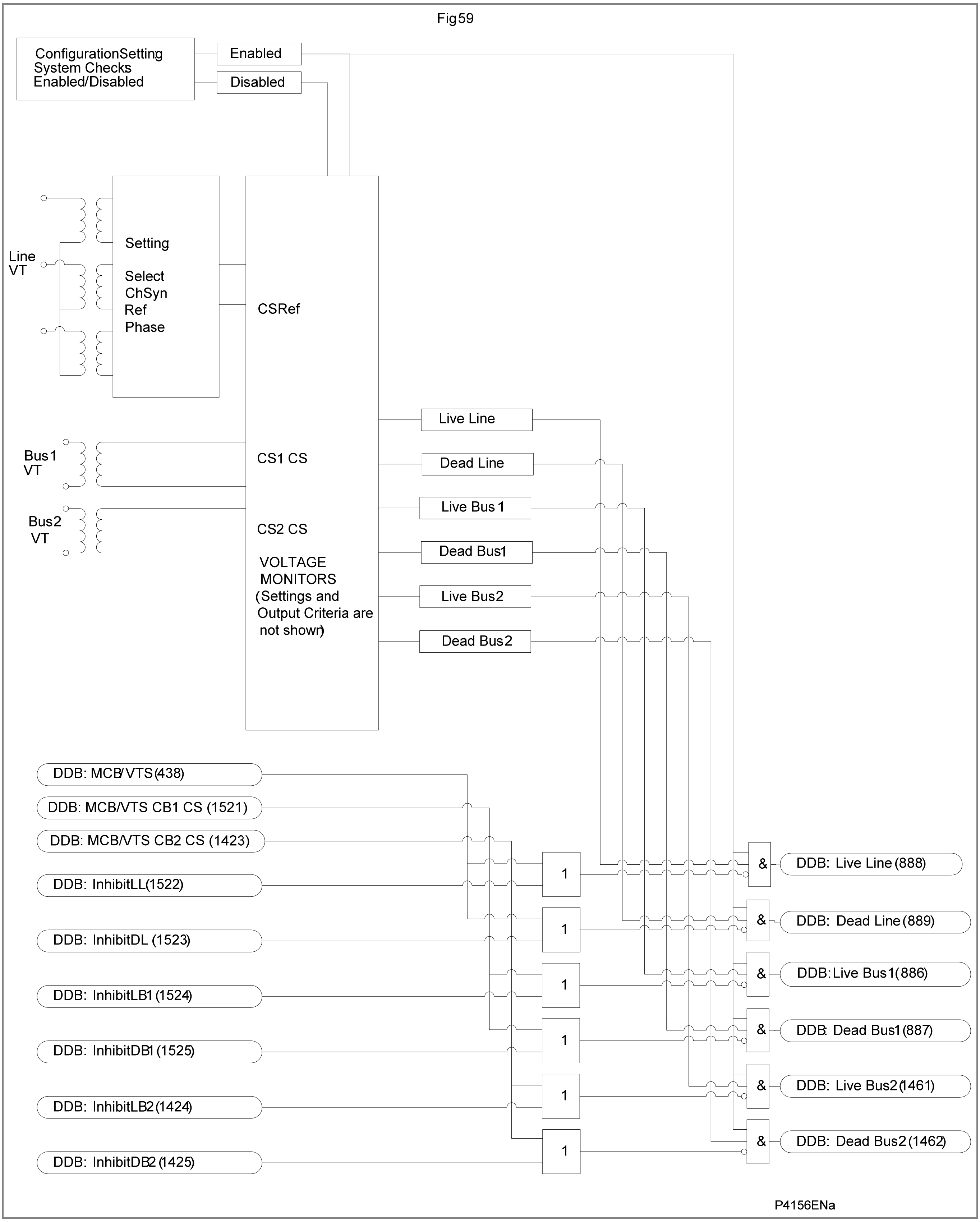


Fig59
ConfigurationSetting System Checks Enabled/Disabled
Enabled
Disabled
Line VT
Setting Select ChSyn Ref Phase
CSRef
Bus1 VT
Bus2 VT
CS1 CS
CS2 CS
VOLTAGE MONITORS (Settings and Output Criteria are not shown)
Live Line
Dead Line
Live Bus 1
Dead Bus1
Live Bus2
Dead Bus2
DDB: MCB/VTS(438)
DDB: MCB/VTS CB1 CS (1521)
DDB: MCB/VTS CB2 CS (1423)
DDB: InhibitLL(1522)
DDB: InhibitDL (1523)
DDB: InhibitLB1 (1524)
DDB: InhibitDB1 (1525)
DDB: InhibitLB2 (1424)
DDB: InhibitDB2 (1425)
1
1
1
1
1
1
&
&
&
&
&
&
DDB: Live Line (888)
DDB: Dead Line (889)
DDB: Live Bus1 (886)
DDB: Dead Bus1 (887)
DDB: Live Bus2 (1461)
DDB: Dead Bus2 (1462)
P4156ENa

Figure AR 168 - System checks - voltage monitor

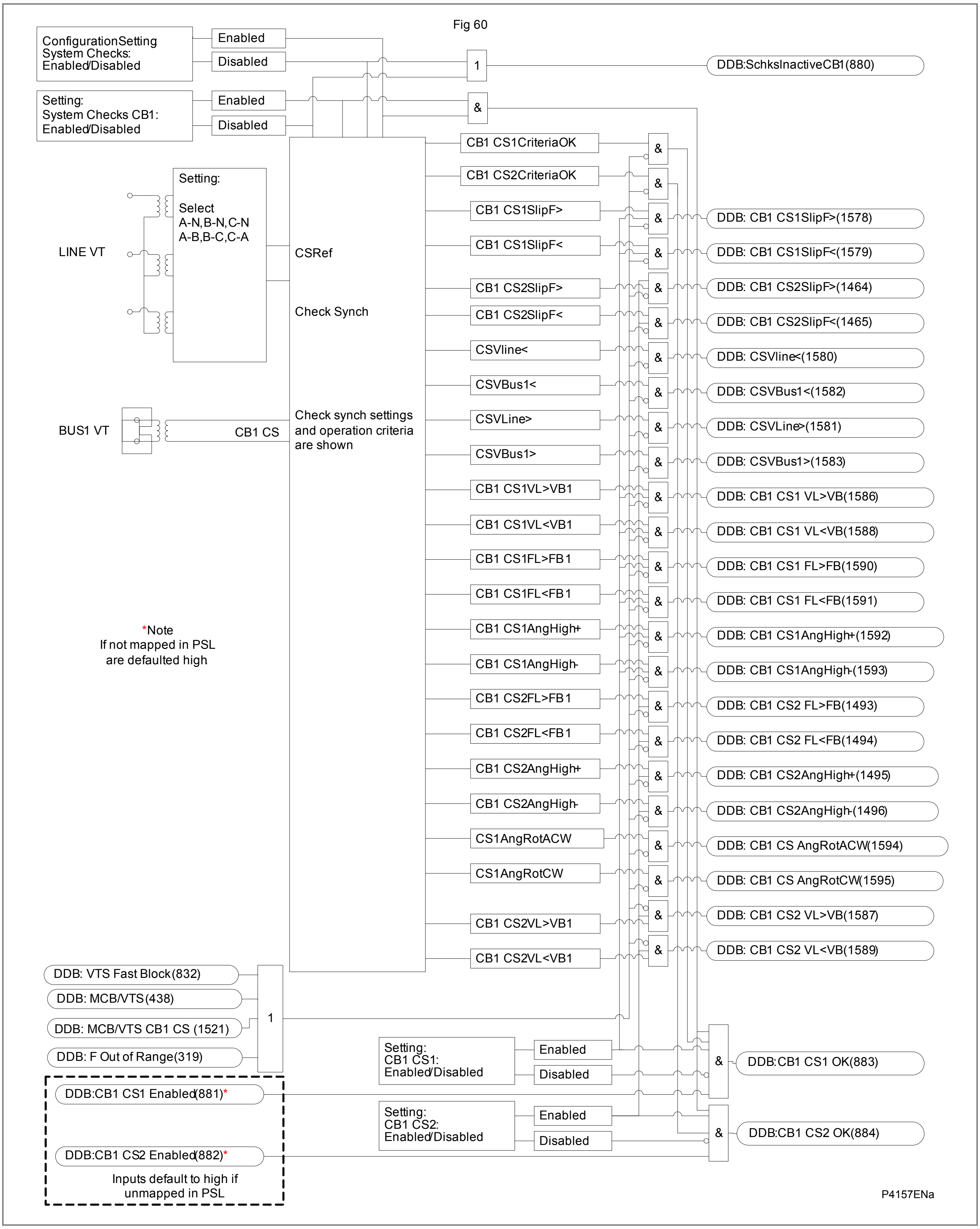


Fig 60
ConfigurationSetting System Checks: Enabled/Disabled
Enabled
Disabled
1
DDB:SchksInactiveCB1(880)
Setting: System Checks CB1: Enabled/Disabled
Enabled
Disabled
&
CB1 CS1CriteriaOK
CB1 CS2CriteriaOK
Setting: Select A-N,B-N,C-N A-B,B-C,C-A
LINE VT
CSRef
Check Synch
BUS1 VT
CB1 CS
Check synch settings and operation criteria are shown
CB1 CS1SlipF>
DDB: CB1 CS1SlipF>(1578)
CB1 CS1SlipF<
DDB: CB1 CS1SlipF<(1579)
CB1 CS2SlipF>
DDB: CB1 CS2SlipF>(1464)
CB1 CS2SlipF<
DDB: CB1 CS2SlipF<(1465)
CSVline<
DDB: CSVline<(1580)
CSVBus1<
DDB: CSVBus1<(1582)
CSVLine>
DDB: CSVLine>(1581)
CSVBus1>
DDB: CSVBus1>(1583)
CB1 CS1VL>VB1
DDB: CB1 CS1 VL>VB(1586)
CB1 CS1VL<VB1
DDB: CB1 CS1 VL<VB(1588)
CB1 CS1FL>FB1
DDB: CB1 CS1 FL>FB(1590)
CB1 CS1FL<FB1
DDB: CB1 CS1 FL<FB(1591)
CB1 CS1AngHigh+
DDB: CB1 CS1AngHigh+(1592)
CB1 CS1AngHigh-
DDB: CB1 CS1AngHigh-(1593)
CB1 CS2FL>FB1
DDB: CB1 CS2 FL>FB(1493)
CB1 CS2FL<FB1
DDB: CB1 CS2 FL<FB(1494)
CB1 CS2AngHigh+
DDB: CB1 CS2AngHigh+(1495)
CB1 CS2AngHigh-
DDB: CB1 CS2AngHigh-(1496)
CS1AngRotACW
DDB: CB1 CS AngRotACW(1594)
CS1AngRotCW
DDB: CB1 CS AngRotCW(1595)
CB1 CS2VL>VB1
DDB: CB1 CS2 VL>VB(1587)
CB1 CS2VL<VB1
DDB: CB1 CS2 VL<VB(1589)
*Note If not mapped in PSL are defaulted high
DDB: VTS Fast Block(832)
DDB: MCB/VTS(438)
DDB: MCB/VTS CB1 CS (1521)
DDB: F Out of Range(319)
1
Setting: CB1 CS1: Enabled/Disabled
Enabled
Disabled
&
DDB:CB1 CS1 OK(883)
DDB:CB1 CS1 Enabled(881)*
Setting: CB1 CS2: Enabled/Disabled
Enabled
Disabled
&
DDB:CB1 CS2 OK(884)
DDB:CB1 CS2 Enabled(882)*
Inputs default to high if unmapped in PSL
P4157ENa

Figure AR 169 - CB1 synch check signals

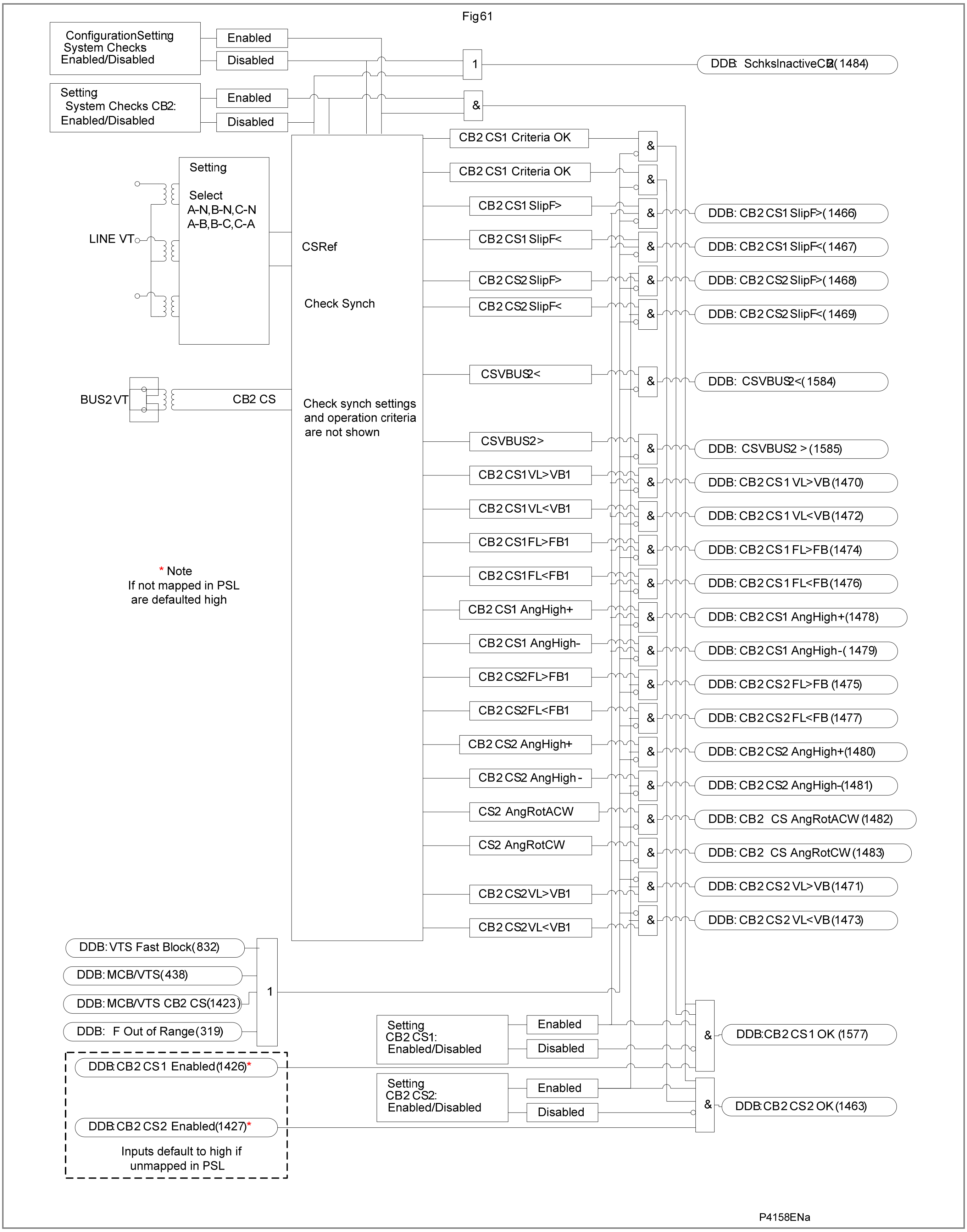


Fig61
Configuration Setting
System Checks
Enabled/Disabled
Enabled
Disabled
1
DDB: SchksInactiveCB2(1484)
Setting
System Checks CB2:
Enabled/Disabled
Enabled
Disabled
&
CB2 CS1 Criteria OK
CB2 CS1 Criteria OK
Setting
Select
A-N,B-N,C-N
A-B,B-C,C-A
LINE VT
CSRef
Check Synch
BUS2 VT
CB2 CS
Check synch settings
and operation criteria
are not shown
CB2 CS1 SlipF>
CB2 CS1 SlipF<
CB2 CS2 SlipF>
CB2 CS2 SlipF<
CSVBUS2<
CSVBUS2>
CB2 CS1 VL>VB1
CB2 CS1 VL<VB1
CB2 CS1 FL>FB1
CB2 CS1 FL<FB1
CB2 CS1 AngHigh+
CB2 CS1 AngHigh-
CB2 CS2 FL>FB1
CB2 CS2 FL<FB1
CB2 CS2 AngHigh+
CB2 CS2 AngHigh-
CS2 AngRotACW
CS2 AngRotCW
CB2 CS2 VL>VB1
CB2 CS2 VL<VB1
&
DDB: CB2 CS1 SlipF>(1466)
DDB: CB2 CS1 SlipF<(1467)
DDB: CB2 CS2 SlipF>(1468)
DDB: CB2 CS2 SlipF<(1469)
DDB: CSVBUS2<(1584)
DDB: CSVBUS2 >(1585)
DDB: CB2 CS1 VL>VB(1470)
DDB: CB2 CS1 VL<VB(1472)
DDB: CB2 CS1 FL>FB(1474)
DDB: CB2 CS1 FL<FB(1476)
DDB: CB2 CS1 AngHigh+(1478)
DDB: CB2 CS1 AngHigh-(1479)
DDB: CB2 CS2 FL>FB(1475)
DDB: CB2 CS2 FL<FB(1477)
DDB: CB2 CS2 AngHigh+(1480)
DDB: CB2 CS2 AngHigh-(1481)
DDB: CB2 CS AngRotACW(1482)
DDB: CB2 CS AngRotCW(1483)
DDB: CB2 CS2 VL>VB(1471)
DDB: CB2 CS2 VL<VB(1473)
* Note
If not mapped in PSL
are defaulted high
DDB: VTS Fast Block(832)
DDB: MCB/VTS(438)
DDB: MCB/VTS CB2 CS(1423)
DDB: F Out of Range(319)
1
Setting
CB2 CS1:
Enabled/Disabled
Enabled
Disabled
Setting
CB2 CS2:
Enabled/Disabled
Enabled
Disabled
DDB:CB2 CS1 Enabled(1426)*
DDB:CB2 CS2 Enabled(1427)*
Inputs default to high if
unmapped in PSL
&
DDB:CB2 CS1 OK (1577)
&
DDB:CB2 CS2 OK(1463)
P4158ENa

Figure AR 170 - CB2 synch check signals

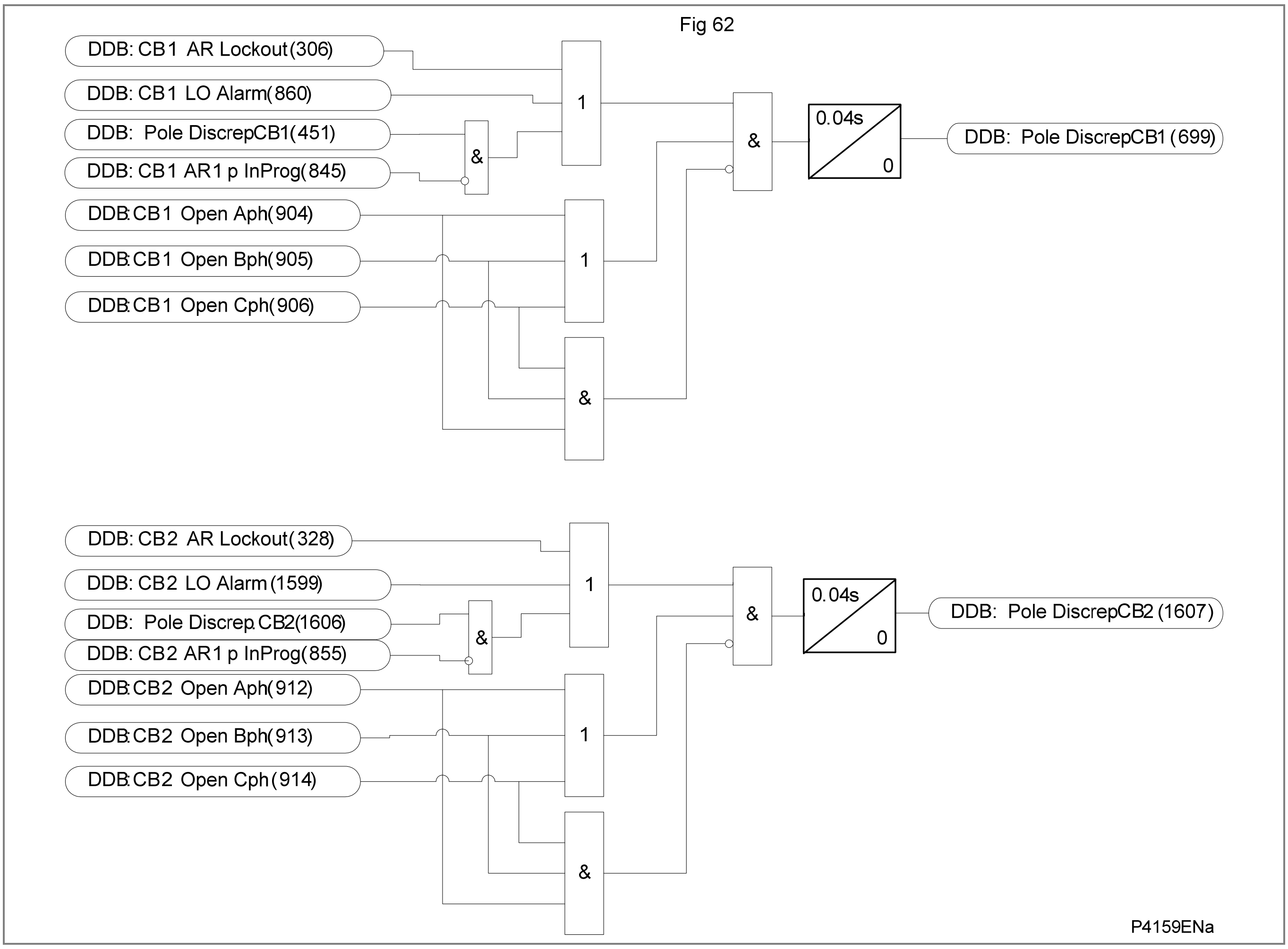


Fig 62
DDB: CB1 AR Lockout(306)
DDB: CB1 LO Alarm(860)
DDB: Pole DiscrepCB1(451)
DDB: CB1 AR1 p InProg(845)
DDB:CB1 Open Aph(904)
DDB:CB1 Open Bph(905)
DDB:CB1 Open Cph(906)
1
&
1
&
&
0.04s
0
DDB: Pole DiscrepCB1 (699)
DDB: CB2 AR Lockout(328)
DDB: CB2 LO Alarm (1599)
DDB: Pole Discrep.CB2(1606)
DDB: CB2 AR1 p InProg(855)
DDB:CB2 Open Aph(912)
DDB:CB2 Open Bph(913)
DDB:CB2 Open Cph(914)
1
&
1
&
&
0.04s
0
DDB: Pole DiscrepCB2 (1607)
P4159ENa

Figure AR 171 - Pole discrepancy

6 P446 CB CONTROL AND AR LOGIC: INTERNAL SIGNALS

The breaker control functionality of the P446 is described in the figures in the previous section. Within that description a number of signals that are internal to the logic of the circuit breaker control are featured. Unlike the DDB signals, these internal signals cannot be accessed using the programmable scheme logic. They are hard-coded into the application software. This section lists those signals and provides a brief description to aid understanding.

Note *This section lists only the hard-coded internal signals used in the circuit breaker control. The DDB signals featuring in the logic are described in the programmable logic section (P44y/EN PL) of this technical manual.*

Name	Description
3PDTCOMP	Int Sig: Three phase dead time complete
AR DISABLED	Int Sig: Overall autoreclosing disabled
BAR CB1	Int Sig from “Autoreclose Lockout - CB1”
BAR CB2	Int Sig from “Autoreclose Lockout - CB2”
CB1 3PDTCOMP	Int Sig: CB1 3PAR dead time complete
CB1 3PFTCOMP	Int Sig: CB1 3PAR follower time complete
CB1 3POK	Int Sig: CB1 OK for 3P AR (leader or follower)
CB1 ARSUCC	Int Sig: CB1 auto-reclose successful
CB1 CS1 AngHigh-	Int Sig + DDB: Line/Bus1 phase angle in range: -CB1 CS1 Angle to -180deg
CB1 CS1 AngHigh+	Int Sig + DDB: Line/Bus1 phase angle in range: +CB1 CS1 Angle to +180deg
CB1 CS1 $F_L<F_B$	Int Sig + DDB: Bus1 F > (Line F + “CB1 CS1 SlipFreqf”)
CB1 CS1 $F_L>F_B$	Int Sig + DDB: Line F > (Bus1 F + “CB1 CS1 SlipFreqf”)
CB1 CS1 OK	Int Sig + DDB: CB1 CS1 is enabled and Line and Bus 1 voltages meet CB1 CS1 settings
CB1 CS1 SlipF<	Int Sig + DDB: Line-Bus 1 slip freq < CB1 CS1 SlipFreq setting
CB1 CS1 SlipF>	Int Sig + DDB: Line-Bus 1 slip freq > CB1 CS1 SlipFreq setting
CB1 CS1 $V_L<V_B$	Int Sig + DDB: Bus1 V > (Line V + “CB1 CS1 VDiff”)
CB1 CS1 $V_L>V_B$	Int Sig + DDB: Line V > (Bus1 V + “CB1 CS1 VDiff”)
CB1 CS2AngHigh-	Int Sig + DDB: Line/Bus1 phase angle in range: -CB1 CS2 Angle to -180deg
CB1 CS2AngHigh+	Int Sig + DDB: Line/Bus1 phase angle in range: +CB1 CS2 Angle to +180deg
CB1 CS2$F_L<F_B$	Int Sig + DDB: Bus1 F > (Line F + “CB1 CS2 SlipFreqf”)
CB1 CS2$F_L>F_B$	Int Sig + DDB: Line F > (Bus1 F + “CB1 CS2 SlipFreqf”)
CB1 CS2OK	Int Sig + DDB: CB1 CS2 is enabled and Line and Bus 1 voltages meet CB1 CS2 settings
CB1 CS2SlipF<	Int Sig + DDB: Line-Bus 1 slip freq < CB1 CS2 SlipFreq setting
CB1 CS2SlipF>	Int Sig + DDB: Line-Bus 1 slip freq > CB1 CS2 SlipFreq setting
CB1 CS2$V_L<V_B$	Int Sig + DDB: Bus1 V > (Line V + “CB1 CS2 VDiff”)
CB1 CS2$V_L>V_B$	Int Sig + DDB: Line V > (Bus1 V + “CB1 CS2 VDiff”)
CB1 FARIP	Int Sig: CB1 ARIP as follower
CB1 LARIP	Int Sig: CB1 ARIP as leader
CB1 Op1P	Int Sig: CB1 open single phase
CB1 Op2/3P	Int Sig: CB1 open on 2 or 3 phases

Name	Description
CB1 OpAny	Int Sig: CB1 open on 1, 2 or 3 phases
CB1 SPOK	Int Sig: CB1 OK for SP AR (leader or follower)
CB1 SysCh Off	Int Sig + DDB: CB1 CS1 & CB1 CS2checks disabled
CB1CRLO	Int Sig: CB1 in service - reset CB1 lockout
CB1F3PAR	Int Sig from “Three Phase AR Cycle Selection”
CB1F3PAROK	Int Sig: CB1 OK to 3Ph AR as follower
CB1FSPAR	Int Sig: CB1 SPAR in progress as follower
CB1FSPAROK	Int Sig: CB1 OK to SP AR as follower
CB1L3PAR	Int Sig from “Three Phase AR Cycle Selection”
CB1L3PAR	Int Sig from “Single Phase AR Cycle Selection”
CB1L3PAROK	Int Sig: CB1 OK to 3Ph AR as leader
CB1LFRC	Int Sig: CB1 failed to reclose as leader
CB1LFRC	Int Sig from “Leader/Follower Logic - 1”
CB1LSPAR	Int Sig from “Single Phase AR Cycle Selection”
CB1LSPAROK	Int Sig: CB1 OK to SP AR as leader
CB1SPDTCOMP	Int Sig: CB1 SP dead time complete
CB1SPFTCOMP	Int Sig: CB1 SP follower time complete
CB2 3PDTCOMP	Int Sig: CB2 3PAR dead time complete
CB2 3PFTCOMP	Int Sig: CB2 3PAR follower time complete
CB2 3POK	Int Sig: CB2 OK for 3P AR (leader or follower)
CB2 ARSUCC	Int Sig: CB2 auto-reclose sucessful
CB2 CS1 AngHigh-	Int Sig + DDB: Line/Bus2 phase angle in range: -CB2 CS1 Angle to -180deg
CB2 CS1 AngHigh+	Int Sig + DDB: Line/Bus2 phase angle in range: +CB2 CS1 Angle to +180deg
CB2 CS1 F_L<F_B	Int Sig + DDB: Bus2 F > (Line F + “CB2 CS1 SlipFreqf”)
CB2 CS1 F_L>F_B	Int Sig + DDB: Line F > (Bus2 F + “CB2 CS1 SlipFreqf”)
CB2 CS1 OK	Int Sig + DDB: CB2 CS1 is enabled and Line and Bus 2 voltages meet CB2 CS1 settings
CB2 CS1 SlipF<	Int Sig + DDB: Line-Bus 2 slip freq < CB2 CS1 SlipFreq setting
CB2 CS1 SlipF>	Int Sig + DDB: Line-Bus 2 slip freq > CB2 CS1 SlipFreq setting
CB2 CS1 V_L<V_B	Int Sig + DDB: Bus2 V > (Line V + “CB2 CS1 VDiff”)
CB2 CS1 V_L>V_B	Int Sig + DDB: Line V > (Bus2 V + “CB2 CS1 VDiff”)
CB2 CS2AngHigh-	Int Sig + DDB: Line/Bus2 phase angle in range: -CB2 CS2 Angle to -180deg
CB2 CS2AngHigh+	Int Sig + DDB: Line/Bus2 phase angle in range: +CB2 CS2 Angle to +180deg
CB2 CS2F_L<F_B	Int Sig + DDB: Bus2 F > (Line F + “CB2 CS2 SlipFreqf”)
CB2 CS2F_L>F_B	Int Sig + DDB: Line F > (Bus2 F + “CB2 CS2 SlipFreqf”)
CB2 CS2OK	Int Sig + DDB: CB2 CS2 is enabled and Line and Bus 2 voltages meet CB2 CS2 settings
CB2 CS2SlipF<	Int Sig + DDB: Line-Bus 2 slip freq < CB2 CS2 SlipFreq setting
CB2 CS2SlipF>	Int Sig + DDB: Line-Bus 2 slip freq > CB2 CS2 SlipFreq setting
CB2 CS2V_L<V_B	Int Sig + DDB: Bus2 V > (Line V + “CB2 CS2 VDiff”)
CB2 CS2V_L>V_B	Int Sig + DDB: Line V > (Bus2 V + “CB2 CS2 VDiff”)
CB2 FARIP	Int Sig: CB2 ARIP as follower

Name	Description
CB2 LARIP	Int Sig: CB2 ARIP as leader
CB2 Op1P	Int Sig: CB2 open single phase
CB2 Op2/3P	Int Sig: CB2 open on 2 or 3 phases
CB2 OpAny	Int Sig: CB2 open on 1, 2 or 3 phases
CB2 SPOK	Int Sig: CB2 OK for SP AR (leader or follower)
CB2 SysCh Off	Int Sig + DDB: CB2 CS1 & CB2 CS2checks disabled
CB2 TAR 2/3Ph	Int Sig: 2Ph or 3Ph trip & AR initiation CB2
CB2 TARA	Int Sig: A Ph trip & AR initiation CB2
CB2 TARB	Int Sig: B Ph trip & AR initiation CB2
CB2 TARC	Int Sig: C Ph trip & AR initiation CB2
CB2 TMEM 1Ph	Int Sig: CB1 1Ph trip +AR AR initiation memory CB2
CB2 TMEM 2/3Ph	Int Sig: CB1 2Ph trip +AR AR initiation memory CB2
CB2 TMEM 3Ph	Int Sig: CB1 3Ph trip +AR AR initiation memory CB2
CB2CRLO	Int Sig: CB2 in service - reset CB2 lockout
CB2F3PAR	Int Sig from “Three Phase AR Cycle Selection”
CB2F3PAROK	Int Sig: CB2 OK to 3Ph AR as follower
CB2FSPAR	Int Sig: CB2 SPAR in progress as follower
CB2FSPAROK	Int Sig: CB2 OK to SP AR as follower
CB2L3PAR	Int Sig from “Three Phase AR Cycle Selection”
CB2L3PAROK	Int Sig: CB2 OK to 3Ph AR as leader
CB2LFRC	Int Sig: CB2 failed to reclose as leader
CB2LFRC	Int Sig from “Leader/Follower Logic - 1”
CB2LSPAR	Int Sig from “Single Phase AR Cycle Selection”
CB2LSPAROK	Int Sig: CB2 OK to SP AR as leader
CB2SPDTCOMP	Int Sig: CB2 SP dead time complete
CB2SPFTCOMP	Int Sig: CB2 SP follower time complete
CBARCancel	Int Sig: Stop and reset CB1 and CB2 AR In progress
CS VBus1<	Int Sig + DDB: Bus1 Volts < CS UV setting
CS VBus1>	Int Sig + DDB: Bus1 Volts > CS OV setting
CS VBus2<	Int Sig + DDB: Bus2 Volts < CS UV setting
CS VBus2>	Int Sig + DDB: Bus2 Volts > CS OV setting
CS VLine<	Int Sig + DDB: Line Volts < CS UV setting
CS VLine>	Int Sig + DDB: Line Volts > CS OV setting
CS1 Ang Rot ACW	Int Sig + DDB: Line freq > (Bus1 freq + 0.001Hz) (CS1 Angle Rotating Anticlockwise)
CS1 Ang Rot CW	Int Sig + DDB: Bus1 freq > (Line freq + 0.001Hz) (CS1 Angle Rotating Clockwise)
CS2 Ang Rot ACW	Int Sig + DDB: Line freq > (Bus2 freq + 0.001Hz) (CS2 Angle Rotating Anticlockwise)
CS2 Ang Rot CW	Int Sig + DDB: Bus2 freq > (Line freq + 0.001Hz) (CS2 Angle Rotating Clockwise)
Dead Bus 1	Int Sig + DDB: CS1 V magnitude < Dead Bus 1 setting
Dead Bus 2	Int Sig + DDB: CS2 V magnitude < Dead Bus 2 setting
Dead Line	Int Sig + DDB: Line V magnitude < Dead Line setting

Name	Description
DeadLineLockout	Int Sig: When setting “3PDT Start When LD” is set to Enabled and the line does not go dead for a time set by “Dead Line Time” then this signal will force the auto-reclose sequence to lockout.
ENABLE CB13PDT	Int Sig: Enable dead time for CB1 3PAR
ENABLE CB1SPDT	Int Sig: Enable dead time for CB1 SPAR
ENABLE CB23PDT	Int Sig: Enable dead time for CB2 3PAR
ENABLE CB2SPDT	Int Sig: Enable dead time for CB2 SPAR
EVOLVE LOCK	Int Sig: Lockout for 2nd trip after Discrim Tim
F Out of Range	Int Sig from frequency tracking logic
FLTMEM 2P	Int Sig: 2 Ph fault memory
FLTMEM 3P	Int Sig: 3 Ph fault memory
Foll CB1	Int Sig from “Leader & Follower Logic - 2”
Foll CB2	Int Sig from “Leader & Follower Logic - 2”
Foll3PAROK	Int Sig from “Leader & Follower AR Modes Enable”
FollSPAROK	Int Sig from “Leader & Follower AR Modes Enable”
INIT AR	Int Sig: Host protection required to initiate AR
Invalid AR Mode	Int Sig: An invalid state is being indicated by the logic that determines AR mode by opto
Last Shot	Int Sig: the last shot
Live Bus 1	Int Sig + DDB: CS1 V magnitude >= Live Bus 1 setting
Live Bus 2	Int Sig + DDB: CS2 V magnitude >= Live Bus 2 setting
Live Line	Int Sig + DDB: Line V magnitude >= Live Line setting
OK Time SP	Int Sig from “Single Phase AR Lead CB Dead Time”
PrefLCB1	Int Sig: CB1 is the preferred leader
PrefLCB2	Int Sig: CB2 is the preferred leader
Prot AR Block*	Int Sig: Host protection required to block AR
Prot Re-op	Int Sig from “Protection Re-operation + Evolving Fault”
RESCB1ARSUCC	Int Sig from “Reset CB1 Successful AR Indication”
RESCB1LO	Int Sig from “Reset CB1 Lockout”
RESCB2ARSUCC	Int Sig from “Reset CB2 Successful AR Indication”
RESCB2LO	Int Sig from “Reset CB2 Lockout”
Reset L-F	Int Sig: From “Protection Re-operation + Evolving fault”
RESPRMEM	Int Sig: Reset “trip & AR” memory
SC Increment	Int Sig: Increment the sequence counter
SCCountoveqShots	Int Sig: Sequence counter has exceeded setting
SET CB1CL	Int Sig from “CB1 Auto Close”
SET CB2CL	Int Sig from “CB2 Auto Close”
SET LCB1	Int Sig: CB1 selected leader
SET LCB1	Int Sig from “Leader/Follower Logic - 1”
SET LCB2	Int Sig: CB2 selected leader
SET LCB2	Int Sig from “Leader/Follower Logic - 1”
SETCB13PCL	Int Sig: CB1 three phase close given
SETCB1SPCL	Int Sig: CB1 single phase close given
SETCB23PCL	Int Sig: CB2 three phase close given
SETCB2SPCL	Int Sig: CB2 single phase close given

Name	Description
SPDTCOMP	Int Sig: Single phase dead time complete
TAR 2/3Ph	Int Sig: 2Ph or 3Ph trip & AR initiation
TARA	Int Sig: A Ph trip & AR initiation
TARANY	Int Sig from “CB1 1 Pole / 3 Pole Trip + AR Initiation”
TARANY	Int Sig: Any trip & AR initiation
TARB	Int Sig: B Ph trip & AR initiation
TARC	Int Sig: C Ph trip & AR initiation
TMEM 1Ph	Int Sig: CB1 1Ph trip +AR AR initiation memory
TMEM 2/3Ph	Int Sig: CB1 2Ph trip +AR AR initiation memory
TMEM 3Ph	Int Sig: CB1 3Ph trip +AR AR initiation memory
TMEM ANY	Int Sig: Any Ph trip & AR initiation memory

Table 30 - P446 CB Control and AR Logic: Internal Signal Definitions

APPLICATION NOTES

CHAPTER 6

Date:	02/2013
Hardware Suffix:	K
Software Version:	57
Connection Diagrams:	10P44303 (SH 01 and 03) 10P44304 (SH 01 and 03) 10P44305 (SH 01 and 03) 10P44306 (SH 01 and 03) 10P44600 10P44601 (SH 1 to 2) 10P44602 (SH 1 to 2) 10P44603 (SH 1 to 2)

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1 INTRODUCTION

1.1 Protection of Overhead Line, Cable, and Hybrid Circuits

Transmission systems are essential to route power from the point of generation to the region of demand. The means of transport is generally via overhead lines, which must have maximum in-service availability. The exposed nature of overhead lines make them fault-prone, and protection devices must trip to initiate isolation of any faulted circuit. In addition to fast fault clearance to prevent plant damage, the requirements for a transmission network must also take into account system stability. Where systems are not highly interconnected the use of single phase tripping and high speed auto-reclosure is often required. This in turn dictates the need for very high speed protection to reduce overall fault clearance times.

Back-up protection is also an important feature of any protection scheme. In the event of equipment failure, such as signaling equipment or switchgear, for example, it is necessary to provide alternative forms of fault clearance. It is desirable to provide back-up protection which can operate with minimum time delay and yet discriminate with both the main protection and protection elsewhere on the system.

The MiCOM provides fast, highly selective protection, to trip for genuine line faults. Advanced load blinding and disturbance detection techniques - such as power swing blocking - ensure stability when no tripping is required. Selectable mho and quadrilateral (polygon) characteristics allow versatile deployment as main protection for all effectively-earthed transmission and distribution circuits, whether lines, cables or hybrid (a mix of part cable, part overhead line).

Comprehensive back-up protection and control functions are also included. A choice between two integrated teleprotection schemes secures fast fault clearance over the whole length of protected lines and reduces the overall scheme cost.

The relay offers powerful recording and monitoring features, to assist with power system diagnosis and fault analysis.

2 APPLICATION OF INDIVIDUAL PROTECTION FUNCTIONS

The following sections detail the individual protection functions in addition to where and how they may be applied. Worked examples are provided, to show how the settings are applied to the relay.

2.1 Simple and Advanced Setting Mode

To the benefit of user, the MiCOM P443 and P446 offer two setting modes for distance protection: “***Simple***” and “***Advanced***”. In the majority of cases, “**Simple**” setting is recommended, and allows the user merely to enter the line parameters such as length, impedances and residual compensation. Then, instead of entering distance zone impedance reaches in ohms, zone settings are entered in terms of **percentage of the protected line**. This makes the relay particularly suited to use along with any installed LFZP Optimho relays, as the reduced number of settings mimics the Autocalc facility within Opticom software.

The “***Advanced***” setting mode is recommended for the networks where the protected and adjacent lines are of dissimilar construction, requiring independent zone characteristic angles and residual compensation. In this setting mode all individual distance ohmic reach and residual compensation settings and operating current thresholds per each zone are accessible. This makes the relay adaptable to any specific application.

2.2 Line Parameters Settings

It is essential (especially when using the “**simple**” setting mode) that the data relating to 100% of the protected line is entered here. Take care to input the Line Impedance that correctly corresponds to either Primary or Secondary, whichever has been chosen as the basis for Settings Values in the Configuration column.

2.2.1 Residual Compensation for Earth/Ground Faults

For earth faults, residual current (derived as the vector sum of phase current inputs (Ia + Ib + Ic) is assumed to flow in the residual path of the earth loop circuit. Thus, the earth loop reach of any zone must generally be extended by a multiplication factor of (1 + kZN) compared to the positive sequence reach for the corresponding phase fault element.

Caution **The kZN Angle is different than previous LFZP, SHNB, and LFZR relays: When importing settings from these older products, subtract. angle $\angle Z_1$.**

2.2.2 Mutual Compensation for Parallel Lines

Typically a mutual cut off factor of 1.5 is chosen to give a good margin of safety between the requirements of correct mutual compensation for faults inside the protected line and eliminating mal-operations for faults on the adjacent line.

2.3 Selection of Distance Operating Characteristic

In general, the following characteristics are recommended:

- Short line applications: Mho phase fault and quadrilateral earth fault zones.
- Open delta (vee-connected) VT applications: Mho phase fault, with earth fault distance **disabled**, and directional earth fault only used for earth fault protection.
- Series compensated lines: Recommend **always** to use mho characteristics for both phase and earth faults.

2.3.1 Phase Characteristic

This phase characteristic selection is common to all zones, allowing mho or quadrilateral selection. Generally, the characteristic chosen will match the utility practice. If applied for line protection similarly to LFZP Optimho, LFZR, SHNB Micromho or SHPM Quadramho models in the Schneider Electric range, a mho selection is recommended. For cable applications, or to set similarly to the MiCOM P441/442/444 models, a quadrilateral selection is recommended.

Figure 1 shows the basic settings needed to configure a forward-looking mho zone, assuming that the load blinder is enabled. Figure 2 shows the basic settings needed to configure a forward-looking quadrilateral zone (blinder not shown).

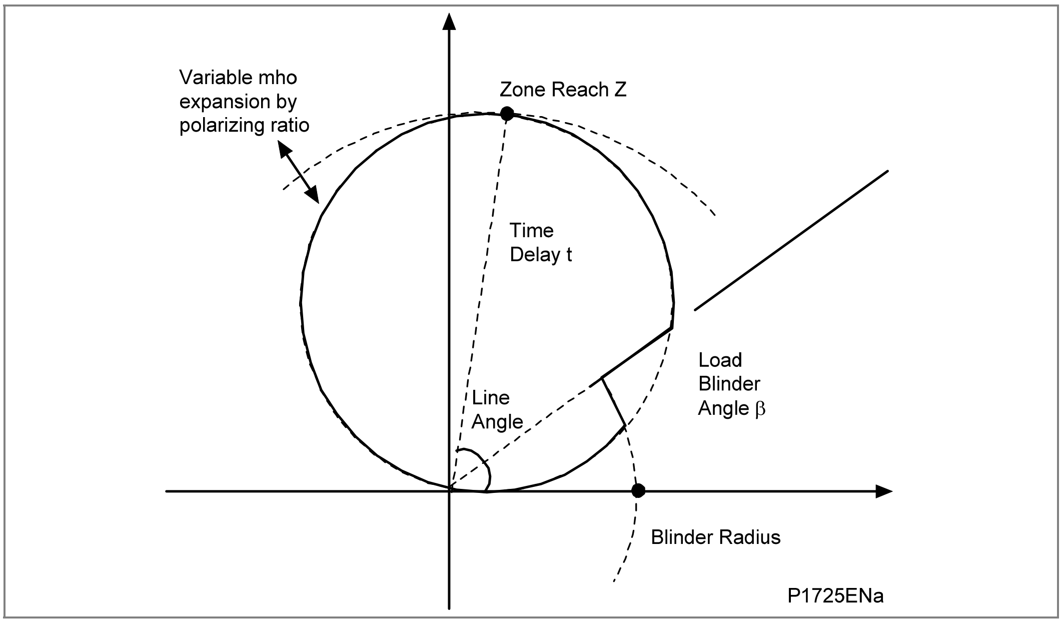


Figure 1 - Settings required to apply a Mho zone

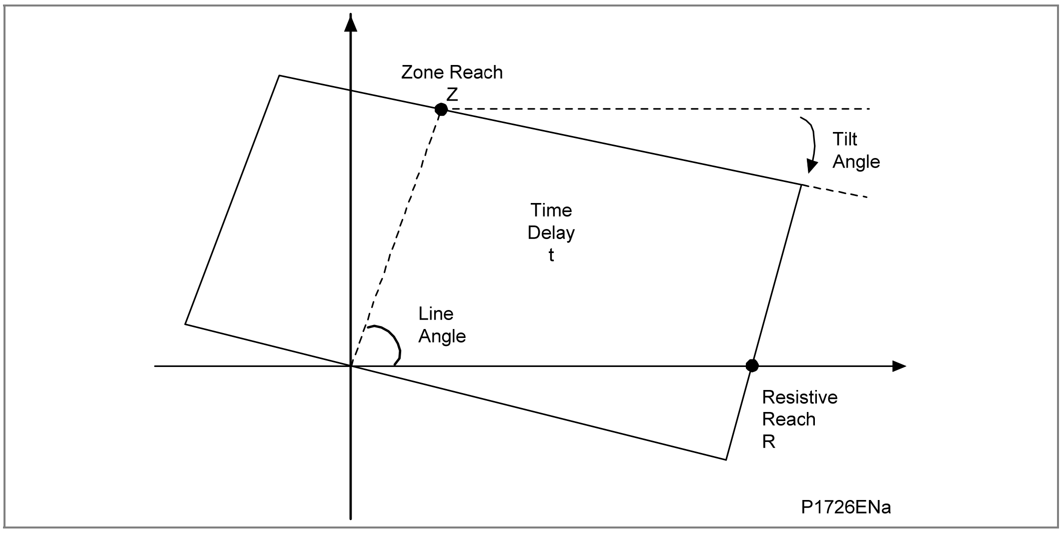


Figure 2 - Settings required to apply a quadrilateral zone

2.3.2 Ground Characteristic

In general, the same setting philosophy would be followed for ground distance protection as is used for the phase elements. This selection is common to all zones, allowing mho or quadrilateral selection and generally, the characteristic chosen will match the utility practice. If applied for long and medium length line protection similarly to LFZP Optimho, LFZR, SHNB Micromho or SHPM Quadramho models in the Schneider Electric range, a mho selection is recommended. For cable applications, or to set similarly to the MiCOM P441/442/444 models, a quadrilateral selection is recommended.

Quadrilateral ground characteristics are also recommended for all lines shorter than 10 miles (16km). This is to ensure that the resistive fault arc coverage is not dependent on mho circle dynamic expansion, but will be a known set value.

2.4 Zone Reaches - Recommended Settings

The Zone 1 elements of a distance relay should be set to cover as much of the protected line as possible, allowing instantaneous tripping for as many faults as possible. In most applications the zone 1 reach (Z1) should not be able to respond to faults beyond the protected line. For an underreaching application the zone 1 reach must therefore be set to account for any possible overreaching errors. These errors come from the relay, the VTs and CTs and inaccurate line impedance data. It is therefore recommended that the reach of the zone 1 distance elements is restricted to 80% of the protected line impedance (positive phase sequence line impedance), with zone 2 elements set to cover the final 20% of the line.

The Zone 2 elements should be set to cover the 20% of the line not covered by zone 1. Allowing for underreaching errors, the zone 2 reach (Z2) should be set in excess of 120% of the protected line impedance for all fault conditions. Where aided tripping schemes are used; fast operation of the zone 2 elements is required. It is therefore beneficial to set zone 2 to reach as far as possible, such that faults on the protected line are well within reach. A constraining requirement is that, where possible, zone 2 does not reach beyond the zone 1 reach of adjacent line protection. For this reason the zone 2 reach should be set to cover ≤50% of the shortest adjacent line impedance, if possible.

The Zone 3 elements would usually be used to provide overall back-up protection for adjacent circuits. The zone 3 reach (Z3) is therefore set to approximately 120% of the combined impedance of the protected line plus the longest adjacent line. A higher apparent impedance of the adjacent line may need to be allowed where fault current can be fed from multiple sources or flow via parallel paths.

Zone 3 may also be programmed with a slight reverse (“**rev**”) offset, in which case its reach in the reverse direction is set as a percentage of the protected line impedance too. This would typically provide back-up protection for the local busbar, where the offset reach is set to 20% for short lines (<30km) or 10% for longer lines.

Zone P is a reversible directional zone. The setting chosen for Zone P, if used at all, will depend upon its application. Typical applications include its use as an additional time delayed zone or as a reverse back-up protection zone for busbars and transformers. Use of zone P as an additional forward zone of protection may be required by some users to line up with any existing practice of using more than three forward zones of distance protection.

The Zone 4 elements may also provide back-up protection for the local busbar. Where zone 4 is used to provide reverse directional decisions for Blocking or Permissive Overreach schemes, zone 4 must reach further behind the relay than zone 2 for the remote end relay. In such cases the reverse reach should be as below (depends on characteristic used):

Mho: Z4 ≥ ((Remote zone 2 reach) x 120%)

Quadrilateral: Z4 ≥ ((Remote zone 2 reach) x 120%) minus the protected line impedance

Note	*In the case of the mho, the line impedance is not subtracted. This ensures that whatever the amount of dynamic expansion of the circle, the reverse looking zone will always detect all solid and resistive faults capable of detection by zone 2 at the remote line end.*

2.5 Quadrilateral Phase Resistive Reaches

Two setting modes are possible for resistive reach coverage:

Common	In this mode, all zones share one common fault resistive reach setting
Proportional	With this mode, the aspect ratio of (zone reach): (resistive reach) is the same for all zones. The "**Fault Resistance**" defines a reference fault at the remote end of the line, and depending on the zone reach percentage setting, the resistive reach will be at that same percentage of the Fault Resistance set. For example, if the zone 1 reach is 80% of the protected line, its resistive reach will be 80% of the reference "**Fault Resistance**".

Proportional setting is used to mimic Germanic protection practice, and to avoid zones being excessively broad (large resistive reach width compared to zone reach length). In general, for easiest injection testing, the aspect ratio of any zone is best within the 1 : 15 range:

1/15th ≤ Z reach / R reach setting ≤ 15

The resistive reach settings (RPh and RG) should be selected according to the utility practice. If no such guidance exists, a starting point for Zone 1 is:

Cables	Choose Resistive Reach = 3 x Zone 1 reach
Overhead lines	Choose Resistive Reach according to the following formula… Resistive reach = [2.3 - 0.0045 x Line length (km)] x Zone 1 reach
Lines longer than 400km	Choose: 0.5 x Zone 1 reach

2.6 Quadrilateral Ground Resistive Reaches and Tilting

Note *Because the fault current for a ground fault may be limited by tower footing resistance, high soil resistivity, and weak infeeding; any arcing resistance is often higher than for a corresponding phase fault at the same location. It may thus be necessary to set the RG ground resistive settings to be higher than the RPh phase setting (i.e. boosted higher than the rule of thumb in the last subsection). A setting of RG three times that of RPh is not uncommon.*

The P443 and P446 allow two different methods of tilting the top reactance line:

- Automatic adjustment of the top reactance line angle
- Fix setting of the top line that will over-ride dynamic tilting

Both methods are detailed in the Operation Section.

2.6.1 Dynamic Tilting:

Medium/Long Lines:

In the case of medium and long line applications where Quad distance ground characteristic is used, the recommended setting is '**Dynamic tilt**' enabled at starting tilt angle of -3° (as per default settings). The -3° is set to compensate for possible CT/VT and line data errors.

For high resistive faults during power exporting, the under-reaching zone 1 is only allowed to tilt down by the angle difference between the faulted phase and negative sequence current ∠(Iph-I2) starting from the –3° set angle. This ensures stability of zone 1 for high resistance faults beyond the zone 1 reach even during heavy load conditions (high load angle between two voltage sources) and sufficient sensitivity for high resistance internal faults. The tilt angle for all other zones (that are by nature over-reaching zones) will remain at -3 deg.

In the case of power importing, zone 1 will remain at –3° whilst all other zones will be allowed to tilt up by the ∠(Iph-I2) angle difference, starting from –3°. This will increase the zone 2 and zone 4 resistive reaches and secure correct operation in POR and blocking type schemes.

Short Lines:

For very short lines, typically below 10 Miles (16km), the ratio of resistive to reactance reach setting (R/X) could easily exceed 10. For such applications the geometrical shape of the Quad characteristic could be such that the top reactance line is close or even crosses the resistive axis as presented in Figure 3.

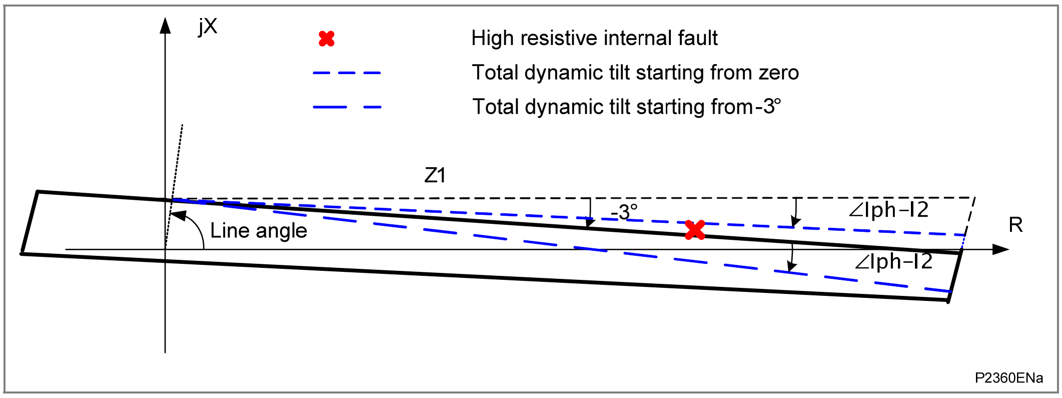

jX
High resistive internal fault
Total dynamic tilt starting from zero
Total dynamic tilt starting from-3°
Z1
-3°
∠Iph–I2
R
Line angle
∠Iph–I2
P2360ENa

Figure 3 - Example of high resistive zone 1 fault that falls outside zone 1 characteristic when the starting tilt angle of -3° is set (over-tilting effect)

In the case of high resistance external faults on a short line, particularly under heavy power exporting conditions, zone 1 will remain stable due to dynamic downwards tilting of the top line as explained earlier but the detection of high resistance internal faults especially towards the end of the line needs consideration. In such applications a user has a choice to either detect high resistance faults using highly sensitive Aided DEF or Delta Directional schemes or to clear the fault with distance ground protection. If distance is to operate, it is necessary to eliminate over-tilting for internal faults by reducing the initial -3° tilting angle to zero so that the overall top line tilt will equal to ∠(Iph-I2) angle only. As per Figure 3, the internal resistive fault will then fall within the zone 1 operating characteristic. However, it should be noted that for short lines the load angle is relatively low when compared to long transmission lines for the same transfer capacity and therefore the top line dynamic tilting may be moderate. Therefore it may be necessary to reduce the zone one reach to guarantee zone 1 stability. This is particularly recommended if distance is operating in an aided scheme. To summarize, for very short lines with large R/X setting ratios, it is recommended to set the initial tilt angle to zero and zone 1 reach to 70-75% of the line impedance.

It should be noted that the above discussion assumes homogenous networks where the angle of the negative sequence current derived at relaying point is very close to the total fault current angle. If the network is non-homogenous, there will be a difference in angle that will cause inaccurate dynamic tilting, hence in such networks either quad with fixed tilt angle or even Mho characteristic should be considered in order to avoid zone 1 over-reach.

Fixed Tilt Angle:

As an alternative to Dynamic tilting, a user can set a fixed tilt angle. This is applicable to applications where the power flow direction is unidirectional.

Exporting End:

To secure stability, the tilt angle of zone 1 at exporting end has to be set negative and above the maximum angle difference between sources feeding the resistive faults. This data should be known from load flow study, but if unavailable, the minimum recommended setting would be the angle difference between voltage and current measured at local end during the heaviest load condition coupled with reduced zone 1 reach of 70-75% of the line impedance.

It should be noted from Figure 3 above that at sharp fixed tilt angle, the effective resistive coverage would be significantly reduced, and therefore for the short lines the dynamic tilting (with variable tilt angle depending on fault resistance and location) is preferred. For all other over-reaching zones set tilting angle to zero.

Importing End:

Set zone 1 tilt angle to zero and for all other zones the typical setting should be positive and between +(5-10)°.

Note	*The setting accuracy for over-reaching zones is not crucial because it will not pose a risk for relay's mal-operation, the purpose is only to boost zone 2 and zone 4 reach and improve distance aided schemes.*

2.6.2 Phase Fault Zone Settings

It can be noted that each zone has two additional settings that are not accessible in the Simple set mode. These settings are:

- A tilt angle on the top line of any quadrilateral set for phase faults;
- A minimum current sensitivity setting.

By factory defaults, the Top Line of quadrilateral characteristics is not fixed as a horizontal reactance line. To account for phase angle tolerances in the line CT, VT and relay itself, the line is tilted downwards, at a "**droop**" of –3°. This tilt down helps to prevent zone 1 overreach.

The fixed ***Tilt*** setting on the phase elements may also be used to compensate for overreach effects when pre-fault heavy load export was flowing. In such cases, fault arc resistance will be phase shifted on the impedance polar plot, tilting down towards the resistive axis (i.e. not appearing to be fully resistive in nature). For long lines with heavy power flow, the Zone 1 top line might be tilted downwards within the range –5 to –15°, mimicking the phase shift of the resistance.

Note	*A minus angle is used to set a downwards tilt gradient, and a positive angle to tilt upwards.*

It should be noted that mho characteristics have an inherent tendency to avoid unwanted overreaching, making them very desirable for long line protection, and one of the reasons for their inclusion within the MiCOM P443 and P446 relays.

The current ***Sensitivity*** setting for each zone is used to set the minimum current that must be flowing in each of the faulted phases before a trip can occur. It is recommended to leave these settings at their default. The exception is where the relay is made more insensitive to match the lesser sensitivity of older relays existing on the power system, or to grade with the pickup setting of any ground overcurrent protection for tee-off circuits.

2.6.3 Distance Directional Principle and Setup

2.6.4 Delta Directional - Selection of RCA

Distance zones are directionalized by the delta decision. For delta directional decisions, the RCA settings must be based on the average source + line impedance angle for a fault anywhere internal or external to the line. Typically, the “**Delta Char Angle**” is set to 60°, as it is not essential for this setting to be precise. When a fault occurs, the delta current will never be close to the characteristic boundary, so an approximate setting is good enough.

The 60° angle is associated with mainly inductive sources and will work perfectly well for most applications. However, in series compensated line applications where the capacitor is physically located behind the line VT the Delta directional characteristic angle needs adjusting. In such applications the capacitor is included in the equivalent source impedance and the overall source impedance as seen by the relay will become predominantly capacitive if the inductance of the source (normally strong source) is less than the capacitor value. In this case, the calculated operating angle during an internal fault may not fall within the default 60° delta directional line operating boundary and that could potentially lead to an incorrect (reverse) directional decision. A zero degree shift will be most suitable for such a fault, but the constraining factor is the case of external faults for which the source is always inductive regardless of the degree of compensation and for which the 60° shift is most appropriate. To ensure correct, reliable and fast operation for both fault locations in case of predominantly capacitive source, a “**Delta Char Angle**” setting of 30° is strongly recommended.

2.7 Distance Setup - Filtering, Load Blinding and Polarizing

2.7.1 Digital Filtering

In most applications, it is recommended that *Standard* filtering is used. This will ensure that the relay offers fast, sub-cycle tripping. In certain rare cases, such as where lines are immediately adjacent to High Voltage DC (HVDC) transmission, the current and voltage inputs may be severely distorted under fault conditions. The resulting non-fundamental harmonics could affect the reach point accuracy of the relay. To prevent the relay being affected, a '***Special***' set of filters are available. It is noted that when using the long line filter the instantaneous operating time is increased by about a quarter of a power frequency cycle.

2.7.1.1 CVTs with Passive Suppression of Ferroresonance

Set a "***Passive***" CVT filter for any type 2 CVT (those with an anti-resonance design). An SIR cutoff setting needs to be applied, above which the relay operation is deliberately slowed by a quarter of a cycle. A typical setting is SIR = 30, below which the relay will trip sub-cycle, and if the infeed is weak the CVT filter adapts to slow the relay and prevent transient overreach.

2.7.1.2 CVTs with active suppression of Ferroresonance

Set an "***Active***" CVT filter for any type 1 CVT.

2.7.2 Load Blinding (Load Avoidance)

For security, it is highly recommended that the blinder is Enabled, especially for lines above 150km (90 miles), to prevent non harmonic low frequency transients causing load encroachment problems, and for any networks where power swings might be experienced.

The impedance radius must be set lower than the worst-case loading, and this is often taken as 120% overloading in one line, multiplied by two to account for increased loading during outages or fault clearance in an adjacent parallel circuit. Then an additional allowance for measuring tolerances results in a recommended setting typically 1/3rd (or even 1/4th in some countries such as UK) of the rated full load current:

$Z \leq$ (Rated phase voltage Vn)/(I_{FLC} x 3)

When the load is at the worst-case power factor, it should remain below the beta setting. So, if we assume a typical worst-case 0.85 power factor, then:

$\beta \geq \text{Cos}^{-1}(0.85)$ plus 15^{o} margin $\geq 47^{o}$

and to ensure that line faults are detected, $\beta \leq$ (Line Angle -15^{o}).

In practice, an angle half way between the worst-case leading load angle, and the protected line impedance angle, is often used.

The MiCOM P443 and P446 have a facility to allow the load blinder to be bypassed any time the measured voltage for the phase in question falls below an undervoltage V< setting. Under such circumstances, the low voltage could not be explained by normal voltage excursion tolerances on-load. A fault is definitely present on the phase in question, and it is acceptable to override the blinder action and allow the distance zones to trip according to the entire zone shape. The benefit is that the resistive coverage for faults near to the relay location can be higher.

The undervoltage setting must be lower than the lowest phase-neutral voltage under heavy load flow and depressed system voltage conditions. The typical maximum V< setting is 70% Vn.

2.7.3 Recommended Polarizing Settings

Cable Applications	In line with LFZP123 or LFZR applications for cable feeders, use only minimum 20% (0.2) memory, which results in minimum mho expansion. This keeps the protected line section well within the expanded mho, thereby ensuring better accuracies and faster operating times for close-up faults.
Series Compensated Lines	Use a mho with maximum memory polarizing (setting = 5). The large memory content will ensure correct operation even with the negative reactance effects of the compensation capacitors seen either within Zs, or within the line impedance.
Short lines	For lines shorter than 10 miles (16km), or with an SIR Higher than 15, use maximum memory polarizing (setting = 5). This ensures sufficient characteristic expansion to cover fault arc resistance.
General Line Applications	Use any setting between 0.2 and 1.

2.8 Distance Elements Basic Scheme Setting

The Zone 1 time delay (tZ1) is generally set to zero, giving instantaneous operation.

The Zone 2 time delay (tZ2) is set to co-ordinate with zone 1 fault clearance time for adjacent lines. The total fault clearance time will consist of the downstream zone 1 operating time plus the associated breaker operating time. Allowance must also be made for the zone 2 elements to reset following clearance of an adjacent line fault and also for a safety margin. A typical minimum zone 2 time delay is of the order of 200ms.

The Zone 3 time delay (tZ3) is typically set with the same considerations made for the zone 2 time delay, except that the delay needs to co-ordinate with the downstream zone 2 fault clearance. A typical minimum zone 3 operating time would be in the region of 400ms.

The Zone 4 time delay (tZ4) needs to co-ordinate with any protection for adjacent lines in the relay's reverse direction.

Note 1	*The MiCOM P443 and P446 allow separate time delays to be applied to both phase and ground fault zones, for example where ground fault delays are set longer to time grade with external ground/earth overcurrent protection.*
Note 2	*Any zone ("#") which may reach through a power transformer reactance, and measure secondary side faults within that impedance zone should have a small time delay applied. This is to avoid tripping on the inrush current when energizing the transformer. As a general rule, if: Z# Reach* $_{setting}$ *>* *50%* X_T *transformer reactance, set: tZ#* $\geq$ *100ms. Alternatively, the 2*nd *harmonic detector that is available in the Programmable Scheme Logic may be used to block zones that may be at risk of tripping on inrush current. Settings for the inrush detector are found in the SUPERVISION menu column.*

Figure 4 shows the typical application of the Basic scheme.

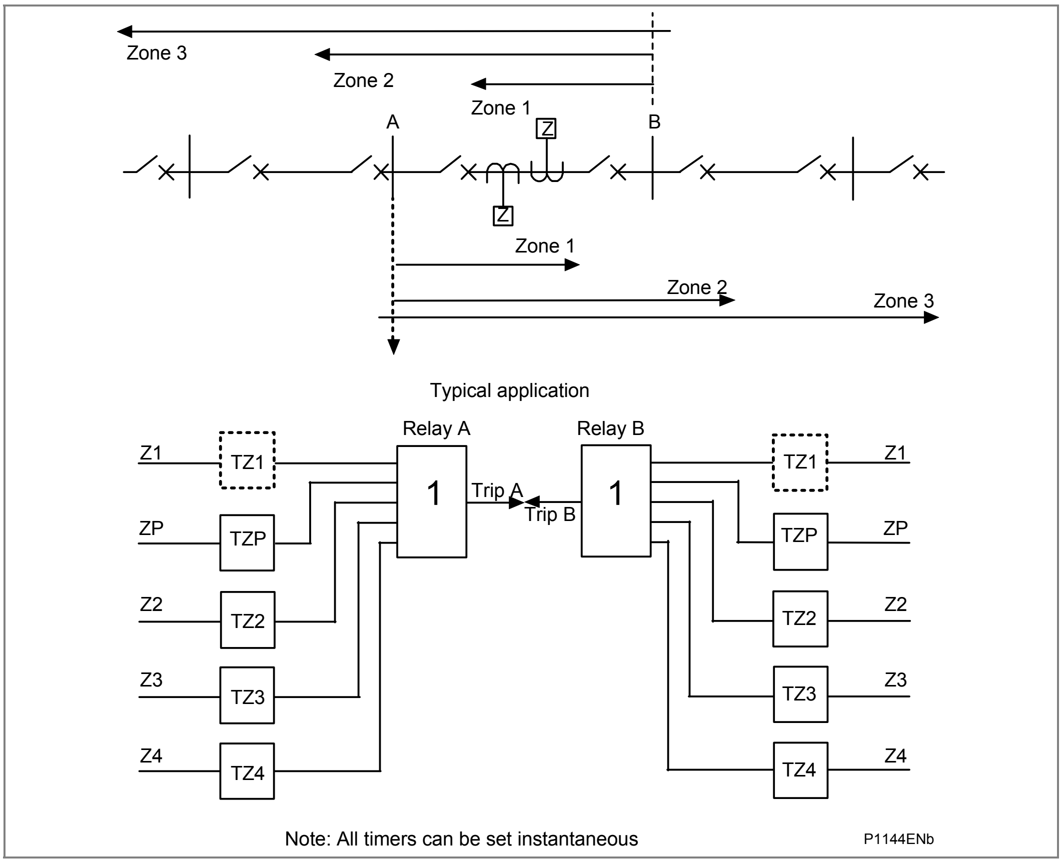

Zone 3
Zone 2
Zone 1
A
B
Z
Z
Zone 1
Zone 2
Zone 3
Typical application
Relay A
Relay B
Z1
TZ1
ZP
TZP
Z2
TZ2
Z3
TZ3
Z4
TZ4
1
Trip A
Trip B
1
TZ1
Z1
TZP
ZP
TZ2
Z2
TZ3
Z3
TZ4
Z4
Note: All timers can be set instantaneous
P1144ENb

Figure 4 - Basic time stepped distance scheme

2.9 Power Swing Alarming and Blocking

The PSB technique employed in the MiCOM P443 and P446 has the significant advantage that it is adaptive and requires no user-set thresholds in order to detect swings faster than 0.5Hz. The PSB relies on the delta techniques internal to the relay, which automatically detect swings. During the power oscillations slower than 0.5Hz the continuous ΔI phase current integral to the detection technique for swing conditions may fall below the sensitive threshold of ΔI=0.05In therefore may not operate. These slow swings will usually occur following sudden load changes or single pole tripping on the weaker systems where the displacement of initial power transfer is not severe. The slow swings of up to 1Hz are by its nature recoverable swings but the swing impedance may stay longer inside the distance characteristics until the oscillations are damped by the power system. Therefore, to guarantee system stability during very slow swings it is recommended to set a blinder to complement the automatic, setting free detection algorithm. Zone 5 is used as a blinder for slow swing detection as well as for the Out Of Step (OST) protection described in the next section. Zone 5 settings are therefore visible even if OST protection is disabled. The slow swing condition will be declared if positive sequence impedance is detected inside zone 5 for more than a cycle without phase selection operation. The slow swing detection operates in parallel to automatic swing detection mechanism.

No system calculation is needed for zone 5 setting, it is only important to set zone 5 smaller than the minimum possible load impedance with a security margin:

In case the OST is enabled the R5, R5’, Z5 and Z5’ settings will be adequate for very slow swing detection. If, however, the OST protection is disabled, set:

R5 = R5’ = 0.85 x Z<

Z5 = Z5’ = 2 x Zline

Where Z< is load blinder radius determined in section 2.7.2.

The user decides which zones are required to be blocked.

Two timers are available:

- The *PSB Reset Delay* is used to maintain the PSB status when ΔI naturally is low during the swing cycle (near the current maxima and minima in the swing envelope). A typical setting of 0.2s is used to seal-in the detection until ΔI has chance to appear again.
- The *PSB Unblock Dly* is used to time the duration for which the swing is present. The intention is to allow the distinction between a stable and an unstable swing. If after the timeout period the swing has still not stabilized, the block for selected zones can be released (“**unblocking**”), giving the opportunity to split the system. If no unblocking is required at the location of this relay, set to maximum (10s).

PSB can be disabled on distribution systems, where power swings would not normally be experienced.

2.9.1 Out of Step Protection

MiCOM P443 and P446 provide an integrated Out of Step protection, thus avoiding a need for a separate stand alone Out of Step relays. Unlike the power swing detection, the Out of Step protection requires settings and is completely independent from the setting free Power swing detection.

This section provides a discussion and a guidance of how to set the Out of Step protection.

Settings based on system studies must be applied when **'Predictive OST'** operation mode is selected as the high setting accuracy is needed to avoid premature system splitting in the case of severe power oscillations that do not lead to pole slip conditions. For the '**OST**' setting the same method may be used but an exhaustive stability study may not be required as it will be shown later that the total system impedance ZT and system split points are adequate to set the relay for this scenario.

The MiCOM P443 and P446 Out of Step protection can operate as a stand alone protection, i.e. Distance protection may be completely disabled under Configuration column.

2.9.2 Critical Stability Angle

What is the angle between two ends when a power system oscillation could be declared as a pole slip? Consider the power angle curves as in Figure 5.

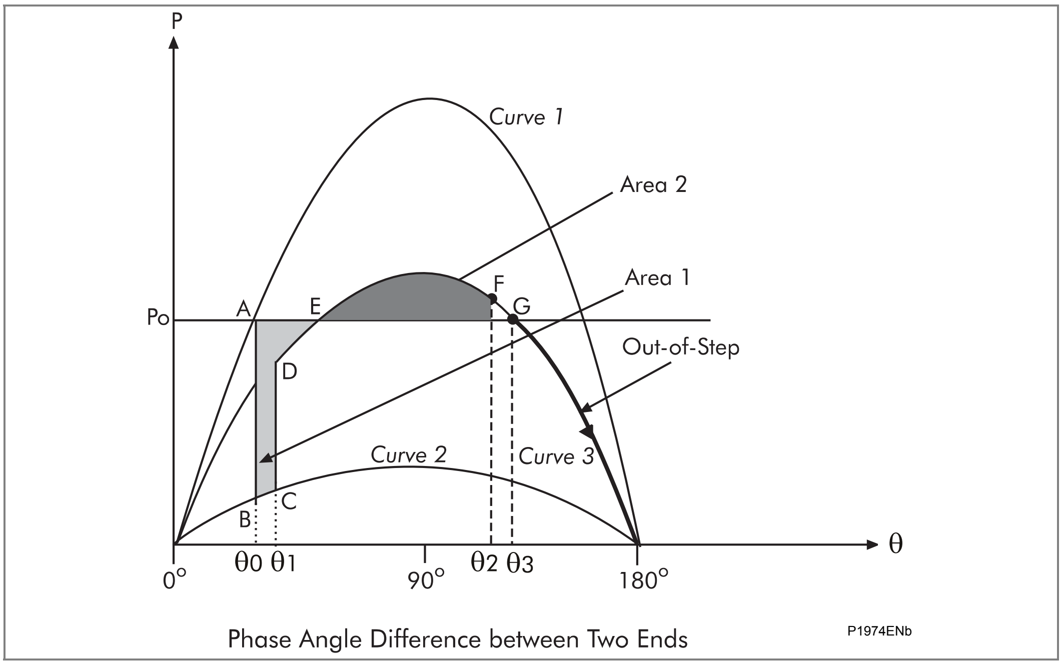


Figure 5 - Power transfer in relation to angle difference θ between 2 ends

Figure 5 represents power angle curves, with no AR being performed, as follows:

Curve 1	Pre-fault system operation via parallel lines where transmitted power is Po
Curve 2	Transmitted power significantly reduced during two-phase to ground fault
Curve 3	New power curve when the parallel line is tripped (fault cleared)

It can be seen that at a fault instance, the operating point A moves to B, with a lower transfer level. There is therefore a surplus of power ΔP=AB at the sending end and the corresponding deficit at the receiving end. The sending end machines start to speed up, and the receiving end machines to slow down, so phase angle θ increases, and the operating point moves along curve 2 until the fault is cleared, when the phase angle is θ1. The operating point now moves to point D on curve 3 which represents one line in service. There is still a power surplus at the sending end, and deficit at the receiving end, so the machines continue to drift apart and the operating point moves along curve 3. If, at some point between E and G (point F) the machines are rotating at the same speed, the phase angle will stop increasing. According to the Equal Area Criterion, this occurs when area 2 is equal to area 1. The sending end will now start to slow down and receiving end to speed up. Therefore, the phase angle starts to decrease and the operating point moves back towards E. As the operating point passes E, the net sending end deficit again becomes a surplus and the receiving end surplus becomes a deficit, so the sending end machines begin to speed up and the receiving end machines begin to slow down. With no losses, the system operating point would continue to oscillate around point E on curve 3, but in practice the oscillation is dumped, and the system eventually settles at operating point E.

To resume, if area 1<area 2, the system will stay in synchronism. This swing is usually called a “**recoverable power swing**”. If, on contrary, the system passes point G with a further increase in angle difference between sending and receiving ends, the system drifts out of synchronism and becomes unstable. This will happen if the initial power transfer Po was set too high in Figure 5, so that the area 1 is greater than area 2. This power swing is not recoverable and is usually called “**out of step**” or “**out of synchronism**” or “**pole slip**” condition. After this, only system separation and re-synchronizing of the machines can restore normal system operation.

In Figure 5, the point G is shown at approximately 120° deg, but it is not true in all cases. If, for example the pre-fault transmitted power (Po) was too high and if the fault clearance was slow, the area 1 will be greater so for the system to recover the angle θ would be close to 90 deg. On contrarily, if the pre-fault transmitted power Po was low and fault clearance fast, the area 1 will be small, so that based on area comparison, the angle θ could go closer to 180 deg and the system will still remain stable.

The actual angle difference at which system will become unstable could only be determined by a particular system studies, but for the purpose of settings recommendation where ‘**OST**’ setting is selected, the typical angle beyond which system will not recover is assumed to be 120 deg.

2.9.2.1 Setting Option Recommendation

The relay provides 4 different setting options:

1. Disabled
2. Predictive OST
3. OST
4. Predictive OST or OST

Set **Option 1** on all lines except the line where tripping due to unrecoverable power oscillations is required or for the system where power oscillations are not severe - mainly in well interconnected systems operating with 3 phase tripping.

Setting **Option 2** (and 4) is the best setting option from the system point of view, perhaps not being widely used in the past. Some utilities prefer an early system split to minimize the angle shift between ends and maximize the chances for the remaining two halves to stabilize as quickly as possible. Special care must be taken when this method is applied to ensure that the actual circuit breaker opening does not occur when the internal voltages at two ends are in anti phase. This is due to the fact that most breakers are not designed to interrupt at double nominal voltage and any attempt to break at that point would lead to flash over and possible circuit breaker damage. The fact is that setting Option 2 (and 4) will be mainly applied do detect and trip fast power oscillations. When this is coupled with a typical 2 cycle circuit breaker operating time, the two voltages angles may rapidly move in opposite directions at the time of opening the circuit breaker. Therefore, if this setting option is chosen, the above facts must be taken into account so that the actual circuit breaker opening must occur well before the angle difference between two ends approaches 180 degrees. On that basis, accurate settings have to be determined based on exhaustive system studies.

Setting **Option 3** is the most commonly used approach. Once the Out of Step conditions are detected, the OST command will split the system at pre-determined points. The slight disadvantages of this method in comparison to Option 2 (and 4) is that the power oscillation will escalate further, thus causing more difficulties for the split parts to remain stable but the advantage is that the timing of the circuit breaker operation (‘**tripping angle**’) is easily controlled and the decision to split the system will be correct even if errors were made in the system data and setting parameters. This extra security is achieved by measuring and confirming the change of polarity of the resistive part of positive sequence impedance on zone 5 exit (reset).

Setting **Option 4** provides 2 stages of Out of Step detection and tripping. If the power system oscillation is very fast, the combination of ∆R and Delta t setting (as discussed below) must be set in such a way that ‘**Predictive OST**’ operates. If however the oscillation is slower, the condition for the ‘**Predictive OST**’ will not be met and the ‘**OST**’ will operate later upon Z5 reset, providing that the change in polarity of the resistive component was detected. This is to distinguish between a slower non-recoverable oscillation and recoverable swings.

2.9.2.2 Blinder Limits Determination

Consider the Out of Step characteristic versus angle θ between two ends.

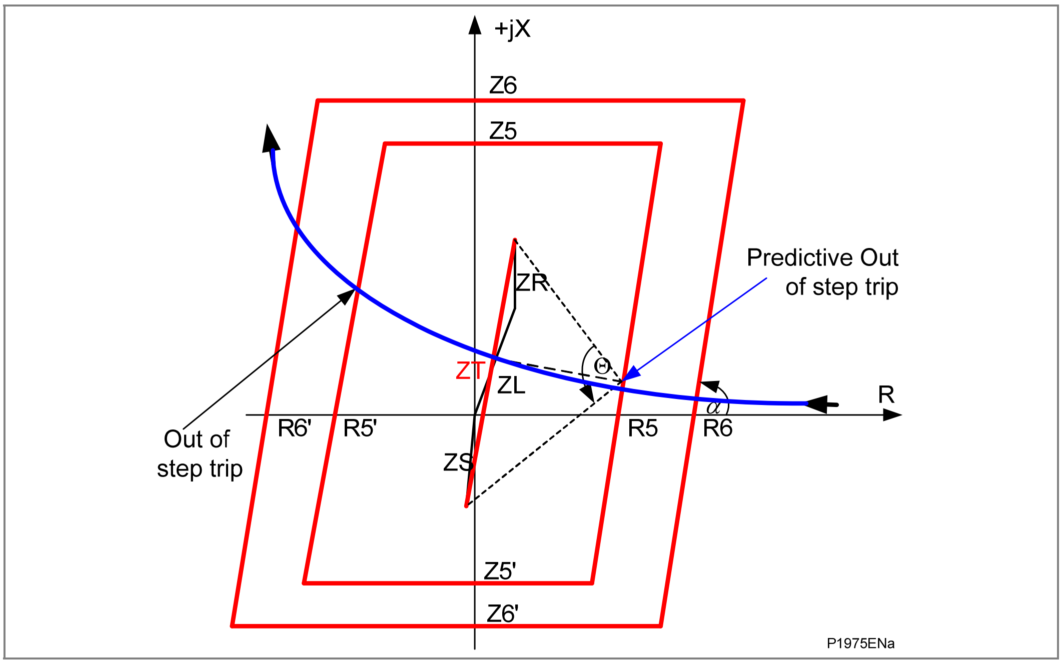


Figure 6 - Setting determination for the positive sequence resistive component R5

Firstly, determine the minimum inner resistive reach R5.

From Figure 6 it can be seen that:

$$R5\min = \frac{\frac{ZT}{2}}{\tan \Theta/2},$$

Where ZT is a total system positive sequence impedance that equals to ZS + ZL + ZS, where ZS and ZR are equivalent positive sequence impedances at the sending and receiving ends and ZL positive sequence line impedance. '**θ**' is an angle difference between the internal voltages at sending and receiving ends beyond which no system recovery is possible.

The next step is to determine the maximum (limit value) for the outer resistive reach R6. It must be insured that Point A in Figure 7 does not overlap with the load area for the worst assumed power factor of 0.85 and the lowest possible ZT angle α.

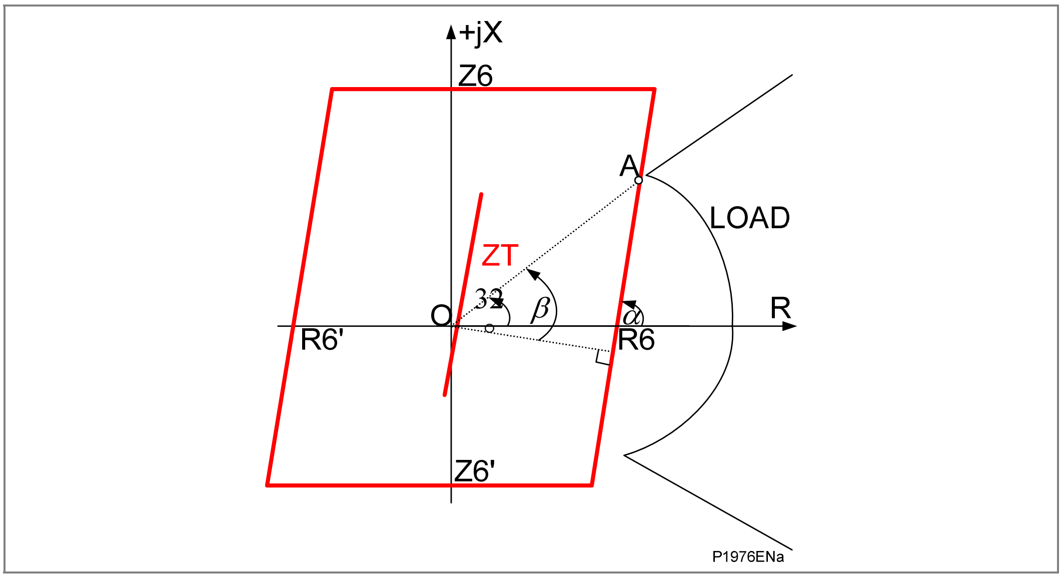


Figure 7 - R6$_{MAX}$ determination

$\beta = 32 + 90 - \alpha$

Z load min = OA

R6MAX < Zload min x cos β

Where:

- Zload min is the minimum load impedance radius calculated above which already has built in sufficient margin
- 32 deg is the load angle that corresponds to the lower power factor of 0.85
- '**α**' is the load blinder angle that matches ZT angle

The setting of negative resistance R5' should equal the R5 to accommodate the '**load import'** condition. Starting from the limit values R5$_{MIN}$ and R6$_{MAX}$ the actual R5 and R6 (including the corresponding R5' and R6') reaches will be set in conjunction with the '**Delta t**' setting below.

Note	*R6$_{MAX}$ reach must be greater than the maximum resistive reach of any distance zone to ensure correct initiation of the 25ms and '**Delta t**' timers. However, the R5$_{MIN}$ reach could be set below the distance maximum resistive reach (inside the distance characteristic) if an extensive resistive coverage is required, meaning that Out of Step protection does not pose a restriction to the quad applications.*

Setting of reactance lines Z5 and Z6 will depend on how far from the relay location the power oscillations are to be detected. Normally, there is only one point where the system is to be initially split and that point will be determined by system studies. For that reason, the Out of Step protection must be enabled at that location and disabled on all others. To detect the Out of step conditions, the Z5'-Z5 and Z6'-Z6 setting must be set to comfortably encompass the total system impedance ZT, as per Figure 7. Typical setting could be:

Z5 = Z5' = 1/2 x 2 ZT = ZT

The Z6 and Z6' setting is not of great importance and could be set to Z6 = Z6' = 1.1 x Z5.

2.9.2.3 Delta t, R5 and R6 Setting Determination

The R5$_{MIN}$ and R6$_{MAX}$ settings determined above are only limit values, the actual R5 and R6 need to be determine in relation to the '**Delta t' timer**.

Predictive OST setting:

For the '**Predictive OST**' setting it is important to:

- Set R6 (and R6') equal to $R6_{MAX}$
- Set R5 as close as practical to $R6_{MAX}$

The aim of pushing the R5 setting to the right is to detect the fast oscillation as soon as possible to gain sufficient time to operate the breaker before the two source voltages are in opposite direction. The only restriction would be the limitation of the '**Delta t**' minimum time delay of 30ms and the speed of oscillation. Set '**Delta t**' so that the following condition is satisfied:

'Delta t' does not expire after positive sequence impedance has passed the R6-R5 region

For this setting, knowledge of the accurate rate of change of swing impedance when crossing the R6-R5 region is essential and therefore must be based on system studies.

Assumption that the rate of change of the positive sequence impedance during crossing the R6-R5 region is average rate of change for the whole swing cycle is wrong and could easily lead to incorrect '**Predictive OST**' operation.

Note	*For the fault, the R6-R5 region will be passed faster than 25ms, therefore even very fast oscillations of 7Hz will not be mistaken with the fault condition and '**Predictive OST**' will not operate.*

OST setting:

For the '**OST**' setting option the precise setting of blinders and '**Delta t**' is not necessary. This is based on the fact that:

The wider the ΔR region and the shorter the Δt setting, any oscillation will be successfully detected. The only condition is that the fault impedance must pass through the ΔR region faster than Δt setting.

Therefore, for the '**OST**' setting assume that $\theta = 120°$ and set:

- $R5 = R5' = R5_{MIN} = ZT/3.46$
- $R6 = R6' = R6_{MAX}$
- Delta t = 30ms

The point is that '**Delta t**' always expires, therefore the above setting will secure the detection of a wide range of oscillations, starting from very slow oscillations caused by recoverable swings up to the fastest oscillation of 7Hz. It should be noted that any fault impedance will pass the R6-R5 region faster than the minimum settable '**Delta t**' time of 30ms.

Predictive OST or OST setting:

As per '**Predictive OST**' above.

2.9.2.4 Tost (Trip Delay) Setting

Tost must be set zero for setting Option 2 and 4 above.

For setting Option 3, Tost should normally be set to zero. It is only the case if a user wants to operate breaker at the angle closer to 360 degrees (when voltages are in phase) when time delay could be applied.

2.9.2.5 Blinder Angle Setting

Set blinders angle '**α**' same as total system impedance ZT angle.

2.9.2.6 Out of Step Operation on Series Compensated Lines

The maximum phase currents during out of step condition rarely exceed 2xIn RMS, which corresponds to the minimum swing impedance passing through zone 1. Since the

Metal-Oxide Varistors (MOV) bypass level is normally set between 2-3In, they will not operate during the power oscillations and therefore in majority of applications will not make any impact on Out of Step operation.

Consider a worst case scenario when the power oscillations are triggered upon fault clearance on the parallel line. In that case approximately twice the load current will start flowing through the remaining circuit, increase further and eventually exceed the MOV threshold. Since the R6-R5 region is usually set far from zone 1 the chances that the positive sequence impedance's trajectory may traverse in and out of the set ∆R region due to MOV operation, are remote. If MOVs do operate within the ∆R region (see Figure 8), a timer, that has been initiated, may reset and be re-initiated or the impedance may remain within ∆R region for a slightly longer duration. This is due to the fact that resistive and capacitive components will be added to the measured impedance during MOV operation as per Figure 8. This effect may have an impact on the **Delta t** measurement if the **Predictive OST** setting is used. If the recommendation to set $R5_{MIN}$ as close as practically possible to the $R6_{MAX}$ is followed, the chances that the swing currents will exceed MOV threshold within the ∆R region is very remote. If a study shows that the MOVs could operate within the ∆R region, it is recommended to set the **Predictive OST and OST** operating mode to cover all eventualities.

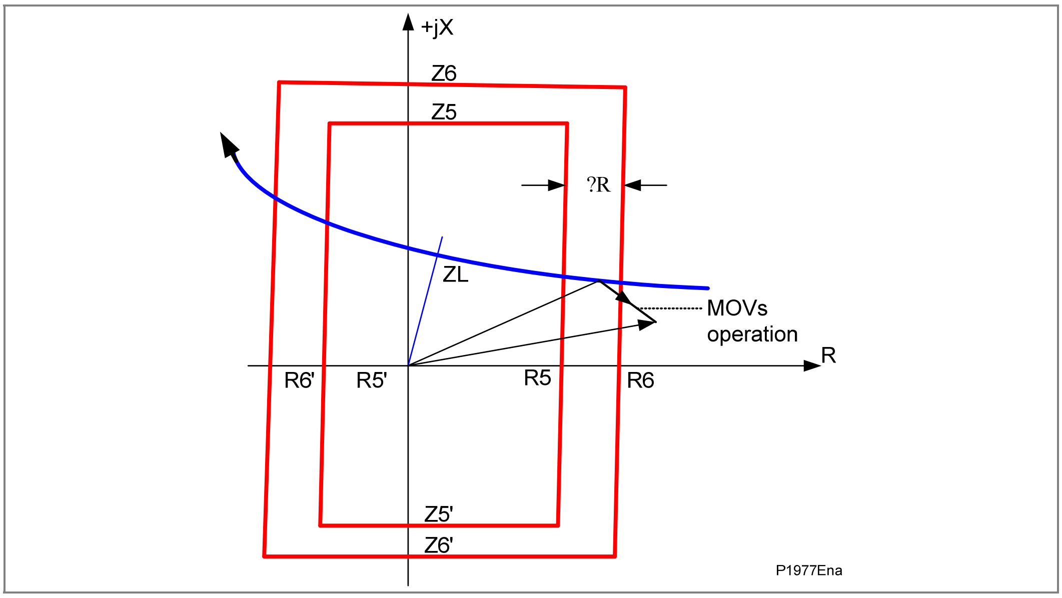


Figure 8 - Example of timer reset due to MOV operation

It should be noted that if '**OST**' setting is chosen, the timer when triggered, will eventually expire as the power oscillations progress, therefore MOV operation will not have any impact on Out of Step operation.

2.10 Switch On To Fault (SOTF) and Trip On Reclose (TOR)

2.10.1 Switch Onto Fault Mode

To ensure fast isolation of faults (for example a closed three phase earth/grounding switch) upon energization, it is recommended this feature is enabled with appropriate zones and/or '**Current No Volt**' (CNV) level detectors, depend on utility practices.

When busbar VTs are used, ‘**Pole Dead**’ signal will not be produced and a user has to connect circuit breaker auxiliary contacts for correct operation. This is not necessary if the SOTF is activated by an external pulse.

SOTF delay	The time chosen should be longer than the slowest delayed-auto-reclose dead time, but shorter than the time in which the system operator might re-energize a circuit once it had opened/tripped. 110 seconds is recommended as a typical setting.
SOTF pulse	Typically this could be set to at 500 ms. This time is enough to establish completely the voltage memory of distance protection.
TOC reset delay	500ms is recommended as a typical setting (chosen to be in excess of the 16 cycles length of memory polarizing, allowing full memory charging before normal protection resumes).

2.10.2 Trip on Re-Close Mode

To ensure fast isolation of all persistent faults following the circuit breaker re-closure. It is recommended this feature is enabled with appropriate zones selected and/or ‘**Current No Volt**’ (CNV) level detectors.

TOC Delay	The TOR is activated after ‘**TOC Delay**’ has expired. The setting must not exceed the minimum AR Dead Time setting to make sure that the TOR is active immediately upon re-close command.
TOC reset delay	500ms is recommended as a typical setting (as per SOTF).

2.11 Directional Function - Setup of DEF and Directional Comparison Elements

2.11.1 DEF Zero Sequence Polarization

In practice, the typical zero sequence voltage on a healthy system can be as high as 1% (i.e.: 3% residual), and the VT error could be 1% per phase. A *VNpol Set* setting between 1% and 4%.Vn is typical, to avoid spurious detection on standing signals. The residual voltage measurement provided in the "**Measurements**" column of the menu may assist in determining the required threshold setting during commissioning, as this will indicate the level of standing residual voltage present. The Virtual Current Polarizing feature will create a VNpol which is always large, regardless of whether actual VN is present.

With DEF, the residual current under fault conditions lies at an angle lagging the polarizing voltage. Hence, negative characteristic angle settings are required for DEF applications. This is set in cell '**DEF Char Angle**' in the relevant earth fault menu.

The following angle settings are recommended for a residual voltage polarized relay:

Distribution systems (solidly earthed) ⇒ -45°

Transmissions systems (solidly earthed) ⇒ -60°

2.11.2 DEF Negative Sequence Polarization

For negative sequence polarization, the RCA settings must be based on the angle of the upstream negative phase sequence source impedance. A typical setting is -60°.

2.11.3 General Setting Guidelines for DEF (Directional Ground Overcurrent)

DEF forward threshold	This setting determines the current sensitivity (trip sensitivity) of the DEF aided scheme. This setting must be set higher than any standing residual current unbalance. A typical setting will be between 10 and 20% In.
DEF reverse threshold	This setting determines the current sensitivity for the reverse ground fault. The setting must always be below the DEF forward threshold for correct operation of Blocking scheme and to provide stability for current reversal in parallel line applications. The recommended setting is 2/3 of DEF forward setting.

Note *This setting has to be above the maximum steady state residual current unbalance.*

2.11.4 Delta Directional Comparison Principle and Setup

For delta directional decisions, the RCA settings must be based on the average source + line impedance angle for a fault anywhere internal or external to the line. Typically, the "**Delta Char Angle**" is set to 60°, as it is not essential for this setting to be precise. When a fault occurs, the delta current will never be close to the characteristic boundary, so an approximate setting is good enough.

2.11.5 Delta Directional Comparison - Selection of ∆I and ∆V Threshold

For best performance, it is suggested that the delta I Fwd current threshold is set at 10 to 20% In. This will ensure detection of all fault types, provided that the fault current contribution to an earth fault at the remote end of the line will generate at least this amount of delta. Selection of the correct Delta V Forward setting is achieved with reference to the following table (SIR = Source to Line impedance ratio):

Lowest SIR Ratio of the System	Recommended ∆V Fwd (as a % of Vn)
≥ 0.3	4%
≥ 0.5	6%
≥ 1	9%
≥ 2	13%
≥ 3	15%
≥ 5	17%
≥10	19%
25 – 60	21%

Table 1 - Selection of the correct Delta V Forward setting

For the reverse fault detectors, these must be set more sensitively, as they are used to invoke the blocking and current reversal guard elements. It is suggested that all reverse detectors are set at 66 to 80% of the setting of the forward detector, typically:

Delta V Rev = Delta V Fwd x 0.66

Delta I Rev = Delta I Fwd x 0.66

This setting philosophy is in-accordance with the well-proven Schneider Electric LFDC relay.

Note *Deltas by their nature are present only for 2 cycles on fault inception. If any distance elements are enabled, these will automatically allow the delta forward or reverse decisions to "**seal-in**", until such time as the fault is cleared from the system. Thus, as a minimum, some distance zone(s) must be enabled as fault detectors. It does not matter what time delay is applied for the zone(s) - this can either be the typical distance delay for that Zone, or set to maximum (10s) if no distance tripping is required. As a minimum, Zone 3 must be enabled, with a reverse reach such as to allow seal-in of Delta Rev, and a forward reach to allow seal-in of Delta Fwd. The reaches applicable would be:*

- Zone 3 Forward — Set at least as long as a conventional Zone 2 (120-150% of the protected line)
- Zone 3 Reverse — Set at least as long as a conventional Zone 4, or supplement by assigning Zone 4 itself if a large reverse reach is not preferred for Zone 3.

A mho characteristic is generally advised in such starter applications, although quadrilaterals are acceptable. As the mho starter is likely to have a large radius, applying the Load Blinder is strongly advised.

2.12 Channel Aided Schemes

The MiCOM P443 and P446 offer two sets of aided channel ("**pilot**") schemes, which may be operated in parallel.

Aided Scheme 1	May be keyed by distance and/or DEF and/ or delta directional comparison
Aided Scheme 2	May be keyed by distance and/or DEF and/ or delta directional comparison

When schemes share the same channel, the same generic scheme type will be applied - i.e. ALL Permissive Overreach, or ALL Blocking.

2.12.1 Distance Scheme PUR - Permissive Underreach Transfer Trip

This scheme is similar to that used in the LFZP Optimho, SHNB Micromho, LFZR, and MiCOM P44x (note 1) distance relays. (Note 1: matches PUP Z2 mode in P441/442/444). It allows an instantaneous Z2 trip on receipt of the signal from the remote end protection.

Send logic: Zone 1

Permissive trip logic: Zone 2 plus Channel Received

The "**Dist dly**" trip time setting should be set to Zero, for fast fault clearance.

2.12.2 Distance Scheme POR - Permissive Overreach Transfer Trip

This scheme is similar to that used in the LFZP Optimho, SHNB Micromho, LFZR, and MiCOM P44x (note 2) distance relays. (Note 2: matches POP Z2 mode in P441/442/444, and POR2 scheme in LFZP/LFZR).

Note	*The POR scheme also uses the reverse looking zone 4 of the relay as a reverse fault detector. This is used in the current reversal logic and in the optional weak infeed echo feature.*

Send logic: Zone 2

Permissive trip logic: Zone 2 plus Channel Received

The "**Dist dly**" trip time setting should be set to Zero, for fast fault clearance.

2.12.3 Permissive Overreach Trip Reinforcement

The send logic in the POR scheme is done in such a way that for any trip command at the local end, the relay sends a channel signal to the remote end(s) in order to maximize the chances for the fault to be isolated at all ends. It should be noted that the send signal that is generated by the '**Any trip**' command is sent on both channels, Ch1 and Ch2, if more than one channel is in use. This feature is termed "**permissive trip reinforcement**", and is a deliberate attempt to ensure that synchronous tripping occurs at all line ends.

2.12.4 Permissive Overreach Scheme Weak Infeed Features

Where weak infeed tripping is employed, a typical voltage setting is 70% of rated

phase-neutral voltage. Weak infeed tripping is time delayed according to the **WI Trip Delay** value, usually set at 60ms.

2.12.5 Distance Scheme Blocking

To allow time for a blocking signal to arrive, a short time delay on aided tripping, **Dist dly**, must be used, as follows:

Recommended Dly setting = Max. Signaling channel operating time + 1 power frequency cycle.

This scheme is similar to that used in the LFZP Optimho, SHNB Micromho, LFZR, and MiCOM P44x (note 3) distance relays. (Note 3: matches BOP Z2 mode in P441/442/444).

Send logic: Reverse Zone 4

Trip logic: Zone 2, plus Channel NOT Received, delayed by Tp

Note	*Two variants of a Blocking scheme are provided, Blocking 1 and Blocking 2. Both schemes operate identically, except that the reversal guard timer location in the logic changes. Blocking 2 may sometimes allow faster unblocking when a fault evolves from external to internal, and hence a faster trip.*

2.12.6 Permissive Overreach Schemes Current Reversal guard

The recommended setting is:

tREVERSAL GUARD = Maximum signaling channel reset time + 35ms.

2.12.7 Blocking Scheme Current Reversal Guard

The recommended setting is:

- Where Duplex signaling channels are used:

tREVERSAL GUARD = Maximum signaling channel operating time + 20ms.

- Where Simplex signaling channels are used:

tREVERSAL GUARD = Maximum signaling channel operating time - minimum signaling channel reset time + 20ms.

2.12.8 Aided DEF Ground Fault Scheme - Permissive Overreach

This POR scheme is similar to that used in all other Schneider Electric relays.

Send logic: IN> Forward pickup

Permissive trip logic: IN> Forward plus Channel Received

Note	*The Time Delay for a permissive scheme aided trip would normally be set to zero.*

2.12.9 Aided DEF Ground Fault Scheme - Blocking

This scheme is similar to that used in all other Schneider Electric relays.

Send logic: DEF Reverse

Trip logic: IN> Forward, plus Channel NOT Received, with a small set delay

To allow time for a blocking signal to arrive, a short time delay on aided tripping **must** be used. The recommended Time Delay setting = max. Signaling channel operating time + 20 ms.

2.12.10 Delta Scheme POR - Permissive Overreach Transfer Trip

This scheme is similar to that used in the LFDC relay.

Send logic: Δ Fault Forward

Permissive trip logic: Δ Fault Forward plus Channel Received.

The Delta Delay trip time setting should be set to zero, for fast fault clearance.

2.12.11 Delta Blocking Scheme

This scheme is similar to that used in the LFDC relay.

Send logic: Δ Fault Reverse

Trip logic: Δ Fault Forward, plus Channel NOT Received, delayed by Tp.

Recommended Dly setting = Max. signaling channel operating time + 6 ms.

2.12.12 Delta Schemes Current Reversal Guard Timer

Similarly to the distance protection schemes, current reversals during fault clearance on an adjacent parallel line need to be treated with care. In order to prevent mal-operation (mal-tripping) of the protection on the unfaulted line, a current reversal guard timer must be set. The recommended setting for both POR and BLOCKING schemes is:

tREVERSAL GUARD = Maximum signaling channel reset time + 35 ms

2.13 Loss of Load Accelerated Tripping (LoL)

For circuits with load tapped off the protected line, care must be taken in setting the loss of load feature to ensure that the I< level detector setting is above the tapped load current. When selected, the loss of load feature operates in conjunction with the main distance scheme that is selected. In this way it provides high speed clearance for end zone faults when the Basic scheme is selected or, with permissive signal aided tripping schemes, it provides high speed back-up clearance for end zone faults if the channel fails.

2.14 Integral Intertripping

The MiCOM P443 and P446 support integral intertripping in the form of InterMiCOM. InterMiCOM can use an auxiliary EIA(RS)232 connection (MODEM InterMiCOM), or it can use an integral optical fiber communication connection (fiber InterMiCOM, or InterMiCOM^{64}). EIA(RS)232 (MODEM) InterMiCOM provides a single, full duplex communication channel, suitable for connection between two P443/P446 relays. The fiber InterMiCOM (InterMiCOM^{64}) can provide up to two full-duplex communications channels. It can be used to connect two MiCOM P443/P446 using a single channel, or redundancy can be added by using dual communications. Alternatively, InterMiCOM^{64} can be used to connect three MiCOM P443/P446 devices in a triangulated scheme for the protection of Teed feeders. MODEM InterMiCOM and InterMiCOM^{64} are completely independent. They have separate settings, are described by separate DDB signals.

As a general rule, where possible, InterMiCOM^{64} would be preferable from an application point of view since it is faster, and based on optical fibres it has high immunity to electromagnetic interference. If the high speed communication channel requirement of InterMiCOM^{64} cannot be provided, EIA(RS)232 provides a cost effective alternative.

Because of the differences between the implementation of EIA(RS)232 InterMiCOM and InterMiCOM^{64}, the settings associated with each implementation are different. Refer to P44y/EN ST for details of all settings. There are settings to prevent inadvertent cross-connection or loopback of communications channels (address settings), settings to accommodate different channel requirements (baud rate, clock source, channel selection) as well as the different settings used for channel quality monitoring and signal management actions in the event of channel failures.

The received InterMiCOM signals are continually monitored for quality and availability. In the event of quality or availability of the received signals falling below set levels, an alarm can be raised.

Note	*An alarm indicating that the signaling has failed, refers only to the incoming signals. The remote relay monitors the other direction of the communications link for quality of transmission. If indication of the quality of the signal transmitted from the local relay for reception at the remote relay is required, one of the InterMiCOM command channels can be used to reflect this back.*

2.14.1 EIA(RS)232 InterMiCOM (Modem InterMiCOM)

The settings necessary for the implementation of MODEM InterMiCOM are in two columns of the relay menu structure. The first column entitled **INTERMICOM COMMS** contains all the information to configure the communication channel and also contains the channel statistics and diagnostic facilities. The second column entitled **INTERMICOM CONF** selects the format of each signal and its fallback operation mode.

The settings required for the InterMiCOM signaling are largely dependant on whether a direct or indirect (modem/multiplexed) connection between the scheme ends is used.

Direct connections are either short metallic or dedicated fiber optic based (using suitable EIA (RS) 232 to optical fiber converters) so can be set to the highest signaling speed of 19200b/s. Due to this high signaling rate, the difference in operating speed between the direct, permissive and blocking type signals is so small that the most secure signaling (direct intertrip) can be selected without any significant loss of speed. In turn, since the direct intertrip signaling requires the full checking of the message frame structure and CRC checks, it is safer to set the **IM# Fallback Mode** to **Default** with a minimal intentional delay by setting **IM# FrameSyncTim** to 10 msecs. Whenever two consecutive messages have an invalid structure, the relay immediately reverts to the default value until a new valid message is received.

For indirect connections, the settings that should be applied become more dependent on applications and communication media . For direct connections, consider only the fastest baud rate but this usually increases the cost of the modem/multiplexer. Also devices operating at these high baud rates may suffer from “data jams” during periods of interference. In the event of communication interruptions, devices may require longer re-synchronization periods. Both of these factors reduce the effective communication speed, leading to a recommended baud rate setting of 9.6 kbit/s. Lower baud rates provide more reliable communications with fewer interruptions, but overall signaling times increase.

Since it is likely that slower baud rates will be selected, the choice of signaling mode becomes significant. However, once the signaling mode has been chosen it is necessary to consider what should happen during periods of noise when message structure and content can be lost. If **Blocking** mode is selected, only a small amount of the total message is actually used to provide the signal, which means that in a noisy environment there is still a good likelihood of receiving a valid message. In this case, it is recommended that the **IM# Fallback Mode** is set to **Default** with a reasonably long **IM# FrameSyncTim**. A typical default selection of Default = 1 (blocking received substitute) would generally apply as the failsafe assignment for blocking schemes.

If **Direct Intertrip** mode is selected, the whole message structure must be valid and checked to provide the signal, which means that in a very noisy environment the chances of receiving a valid message are quite small. In this case, it is recommended that the **IM# Fallback Mode** is set to **Default** with a reasonably long **IM# FrameSyncTim** setting, therefore whenever a non-valid message is received, InterMiCOM uses the set default value. A typical default selection of Default = 0 (intertrip NOT received substitute) generally applies as the failsafe assignment for intertripping schemes.

If **Permissive** mode is selected, the chance of receiving a valid message is between that of the **Blocking** and **Direct Intertrip** modes. In this case, it is possible that the **IM# Fallback Mode** is set to **Latched**. The following table highlights the recommended **IM# FrameSyncTim** settings for the different signaling modes and baud rates:

Baud Rate	Minimum Recommended “IM# FrameSyncTim” Setting		Minimum Setting (ms)	Maximum Setting (ms)
	Direct Intertrip Mode	Blocking Mode		
600	100	250	100	1500
1200	50	130	50	1500
2400	30	70	30	1500
4800	20	40	20	1500
9600	10	20	10	1500
19200	10	10	10	1500

Note *No recommended setting is given for the Permissive mode since it is anticipated that* ***Latched*** *operation will be selected. However, if* ***Default mode*** *is selected, the* ***IM# FrameSyncTim*** *setting should be set greater than the minimum settings listed in the table above. If the* ***IM# FrameSyncTim*** *setting is set lower than the minimum setting listed above, there is a danger that the relay will monitor a correct change in message as a corrupted message.*

Table 2 - Recommended IM# FrameSyncTim settings

A setting of 25% is recommended for the communications failure alarm.

2.14.2 InterMiCOM^{64} ("fiber InterMiCOM")

Optical Budgets

InterMiCOM^{64} supports teleprotection schemes using optical fiber communications. The optical fiber communications may connect directly between line ends of the MiCOM scheme, or they may use digital data channels provided by some form of telecommunications multiplexing equipment. Some multiplexers support direct optical fiber connection as described in the IEEE C37.94 standard. Some multiplexers will require connection using an electrical interface. InterMiCOM^{64} has a number of different optical fiber configurations to allow direct electrical connection between line ends, direct multiplexer connection to IEEE 37.94, or, by means of associated P59x interface units, indirect (electrical) multiplexer connections (to G.703, V.35, or X.21).

When applying any of the InterMiCOM^{64} teleprotection schemes, it is important to select the appropriate communications interface. This will depend on the fiber used and distance between devices. The following table shows the optical budgets of the available communications interfaces.

From April 2008	850nm Multi Mode	1300nm Multi Mode	1300nm Single Mode
Min. transmit output level (average power)	-19.8dBm	-6dBm	-6dBm
Receiver sensitivity (average power)	-25.4dBm	-49dBm	-49dBm
Optical budget	5.6dB	43.0dB	43.0dB
Less safety margin (3dB)	2.6dB	40.0dB	40.0dB
Typical cable loss	2.6dB/km	0.8dB/km	0.4dB/km
Max. transmission distance	1km	50.0km	100.0km

Note *From April 2008, the optical budgets and hence also the maximum transmission distances of the 1300nm multi-mode and 1300nm single-mode fiber interfaces have been increased, to the values shown in the table above.*

Table 3 - Optical budgets and maximum transmission distances

The new interface cards are identified by "**43dB**" marked in the centre of the back-plate, visible from the rear of the relay. These new fiber interfaces are fully backward-compatible with the original equivalent interface. However, in order to achieve the increased distance, both/all ends of the P443 scheme would need to use the new interface.

Pre-April 2008 relays will have the original optical budgets and maximum transmission distances, as shown below.

Pre-April 2008	850nm Multi Mode	1300nm Multi Mode	1300nm Single Mode
Min. transmit output level (average power)	-19.8dBm	-10dBm	-10dBm
Receiver sensitivity (average power)	-25.4dBm	-37dBm	-37dBm
Optical budget	5.6dB	27.0dB	27.0dB
Less safety margin (3dB)	2.6dB	24.0dB	24.0dB
Typical cable loss	2.6dB/km	0.8dB/km	0.4dB/km
Max. transmission distance	1km	30.0km	60.0km

Note *P446 did not exist pre-Aril 2008 so the table applies only to P443.*

Table 4 - Optical budgets and maximum transmission distances

The total optical budget is given by transmitter output level minus the receiver sensitivity and will indicate the total allowable losses that can be tolerated between devices. A safety margin of 3dB is also included in the above table. This allows for degradation of the fiber as a result of ageing and any losses in cable joints. The remainder of the losses will come from the fiber itself. The figures given are typical only and should only be used as a guide.

In general, the 1300nm interfaces will be used for direct connections between relays. The 850nm would be used where multiplexing equipment is employed.

Clock Source Setting

A clock source is required to synchronize data transmissions between the system ends. This may be provided either by the MiCOM relays (internal) or may be a function of the telecommunications equipment (external). The relays have a setting for each of Channel 1 and Channel 2 to set the Clock Source to either "**Internal**" or "**External**" according to the communications system configuration.

This setting is not applicable if IEEE C37.94 mode selected.

The Clock Source should be set to "**Internal**" at all system ends, where they are connected by direct optical fiber, as the MiCOM P443/P446 at each end has to supply the clock.

The Clock Source should be set to "**External**" at all system ends, where the ends are connected by multiplexer equipment which is receiving a master clock signal from the multiplexer network. It is important that there is a single master clock source on the multiplexer network and that the multiplexer equipment at each end is synchronized to this clock.

Note This setting is not applicable if IEEE C37.94 mode selected.

Data Rate

The data rate for signaling between the two or three ends may be set to either 64kbit/sec or 56kbit/sec as appropriate.

If there is a direct fiber connection between the ends, the data rate would usually be set to 64kbit/sec, as this gives a slightly faster trip time.

If there is a multiplexer network between the ends, then this will determine the data rate to be used by the MiCOM P443/P446 system. The electrical interface to the multiplexer (G.703 co-directional, V.35, or X.21) will be provided on either a 64kbit/sec or 56kbit/sec channel, and the MiCOM P443/P446 at each end must be set to match this data rate.

Generally, North American multiplexer networks are based on 56kbit/sec (and multiples thereof) channels, whereas multiplexer networks in the rest of the world are based on 64kbit/sec (and multiples thereof) channels.

This setting is not applicable if IEEE C37.94 mode selected.

2.15 Integral Intertripping

The MiCOM P44y supports integral intertripping in the form of InterMiCOM. InterMiCOM can be realized using an auxiliary EIA(RS)232 connection (MODEM InterMiCOM), or it can be realised by means of an integral optical fiber communication connection (fiber InterMiCOM, or InterMiCOM^{64}). EIA(RS)232 (MODEM) InterMiCOM provides a single, full duplex communication channel, suitable for connection between two MiCOM P44y devices. The fiber InterMiCOM (InterMiCOM^{64}) can provide up to two full-duplex communications channels. It can be used to connect two MiCOM P44y devices using a single channel, or redundancy can be added by using dual communications. Alternatively, InterMiCOM^{64} can be used to connect three MiCOM P44y devices in a triangulated scheme for the protection of Teed feeders. MODEM InterMiCOM and InterMiCOM^{64} are completely independent. They have separate settings, are described by separate DDB signals.

As a general rule, where possible, InterMiCOM^{64} would be preferable from an application point of view since it is faster, and based on optical fibers it has high immunity to electro-magnetic interference. If the high speed communication channel requirement of InterMiCOM^{64} cannot be provided, EIA(RS)232 provides a cost effective alternative.

Because of the differences between the implementation of EIA(RS)232 InterMiCOM and InterMiCOM^{64}, the settings associated with each implementation are different. Refer to *P44y/EN ST* for details of all settings. There are settings to prevent inadvertent cross-connection or loopback of communications channels (address settings), settings to accommodate different channel requirements (baud rate, clock source, channel selection) as well as the different settings used for channel quality monitoring and signal management actions in the event of channel failures.

The received InterMiCOM signals are continually monitored for quality and availability. In the event of quality or availability of the received signals falling below set levels, then an alarm can be raised.

Note	*An alarm indicating the signaling has failed, refers only to the incoming signals. The remote relay will monitor the other direction of the communications link for quality of transmission. If indication of the quality of the signal transmitted from the local relay for reception at the remote relay is required, then one of the InterMiCOM command channels can be used to reflect this back.*

2.15.1 EIA(RS)232 InterMiCOM (“Modem InterMiCOM”)

The settings necessary for the implementation of MODEM InterMiCOM are contained within two columns of the relay menu structure. The first column entitled **INTERMICOM COMMS** contains all the information to configure the communication channel and also contains the channel statistics and diagnostic facilities. The second column entitled **INTERMICOM CONF** selects the format of each signal and its fallback operation mode.

The settings required for the InterMiCOM signaling are largely dependant upon whether a direct or indirect (modem/multiplexed) connection between the scheme ends is used.

Direct connections will either be short metallic or dedicated fiber optic based (by means of suitable EIA 232 to optical fiber converters) and hence can be set to have the highest signaling speed of 19200b/s. Due to this high signaling rate, the difference in operating speed between the direct, permissive and blocking type signals is so small that the most secure signaling (direct intertrip) can be selected without any significant loss of speed. In turn, since the direct intertrip signaling requires the full checking of the message frame structure and CRC checks, it would seem prudent that the **IM# Fallback Mode** be set to **Default** with a minimal intentional delay by setting **IM# FrameSyncTim** to 10 msecs. In other words, whenever two consecutive messages have an invalid structure, the relay will immediately revert to the default value until a new valid message is received.

For indirect connections, the settings that can be applied will become more application and communication media dependent. As for the direct connections, consider only the fastest baud rate but this will usually increase the cost of the necessary modem/multiplexer. In addition, devices operating at these high baud rates may suffer from **data jams** during periods of interference and in the event of communication interruptions, may require longer re-synchronization periods. Both of these factors will reduce the effective communication speed thereby leading to a recommended baud rate setting of 9.6 kbit/s. As the baud rate decreases, the communications will become more robust with fewer interruptions, but the overall signaling times will increase.

Since it is likely that slower baud rates will be selected, the choice of signaling mode becomes significant. However, once the signaling mode has been chosen it is necessary to consider what should happen during periods of noise when message structure and content can be lost. If **Blocking** mode is selected, only a small amount of the total message is actually used to provide the signal, which means that in a noisy environment there is still a good likelihood of receiving a valid message. In this case, it is recommended that the **IM# Fallback Mode** is set to **Default** with a reasonably long **IM# FrameSyncTim**. A typical default selection of Default = 1 (blocking received substitute) would generally apply as the failsafe assignment for blocking schemes.

If **Direct Intertrip** mode is selected, the whole message structure must be valid and checked to provide the signal, which means that in a very noisy environment the chances of receiving a valid message are quite small. In this case, it is recommended that the **IM# Fallback Mode** is set to **Default** with a minimum **IM# FrameSyncTim** setting i.e. whenever a non-valid message is received, InterMiCOM will use the set default value. A typical default selection of Default = 0 (intertrip NOT received substitute) would generally apply as the failsafe assignment for intertripping schemes.

If **Permissive** mode is selected, the chance of receiving a valid message is between that of the **Blocking** and **Direct Intertrip** modes. In this case, it is possible that the **IM# Fallback Mode** is set to **Latched**. The table below highlights the recommended **IM# FrameSyncTim** settings for the different signaling modes and baud rates:

Baud rate	Minimum recommended “IM# FrameSyncTim” Setting		Minimum setting (ms)	Maximum setting (ms)
	Direct intertrip mode	Blocking mode		
600	100	250	100	1500
1200	50	130	50	1500
2400	30	70	30	1500
4800	20	40	20	1500
9600	10	20	10	1500
19200	10	10	10	1500

Note *No recommended setting is given for the Permissive mode since it is anticipated that **Latched** operation will be selected. However, if **Default mode** is selected, the **IM# FrameSyncTim** setting should be set greater than the minimum settings listed above. If the **IM# FrameSyncTim** setting is set lower than the minimum setting listed above, there is a danger that the relay will monitor a correct change in message as a corrupted message.*

Table 5 - Recommended IM# FrameSyncTim settings

A setting of 25% is recommended for the communications failure alarm.

IMx Command Type

Many of the same application considerations as per MODEM InterMiCOM apply equally for InterMiCOM^{64}. However, as the data rate is much faster (56 or 64 kbit/s), only the comments relating to fast fiber channels are relevant. Due to the fast data rate, there is not so much difference in real performance between the three generic modes of teleprotection (Direct Intertrip, Permissive and Blocking), so only two are implemented for InterMiCOM^{64}. Direct Intertripping is available, with the second mode a combined mode for Permissive/Blocking (the latter is named as '***Permissive***' in the menu). To increase the security for Intertripping (Direct transfer tripping), the InterMiCOM^{64} Direct command is issued only when 2 valid consecutive messages are received. The recommended setting is:

For Blocking schemes	set	Permissive
For Permissive scheme	set	Permissive
For Transfer (inter)tripping	set	Direct

The setting files provide independent setting for each of the first 8 commands. It should be noted that the remaining 8 commands will have the same settings respectively, i.e. if the IM1 is set to '**Direct**' the same signaling mode will apply to Channel 1 and Channel 2. Due to the fast data rate, there will be minimal speed difference between the two mode options. Both will give a typical operating time (PSL trigger at the send relay, to PSL state change at the receive relay) as shown below:

Channel Mode Setting	Application	Typical Delay (ms)	Maximum (ms)	Comments
Permissive	Direct Fiber	3 to 7	9	Assuming no repeaters (no source of digital "noise").
	Multiplexed Link	5 to 8 + MUX	12 + MUX	For channel bit error rate up to 1 x 10^{-3}.
Direct Intertrip	Direct Fiber	4 to 8	10	Assuming no repeaters (no source of digital "noise").
	Multiplexed Link	6 to 8 + MUX	13 + MUX	For channel bit error rate up to 1 x 10^{-3}.

Table 6 - Typical operating time

When using InterMiCOM^{64} to implement Aided Scheme 1 or Aided Scheme 2, it is suggested to assume a conservative worst-case channel delay of 15ms (pickup and reset delay), for the purposes of blocking and reversal guard calculations. The delay of the multiplexer should be added if applicable, taking into account longer standby path re-routings which might be experienced in the event of self-healing in a SONET/SDH telecomms network.

In 3-terminal applications, where fallback to "**chain"** topology is possible in the event of failure of one communications leg in the triangle, longer times may be experienced. In fallback mode, retransmission of the messages occurs so the path length is doubled. Overall command times to the final end can be doubled.

IMx Fallback Mode

When the '**Default**' setting is selected, the following '**IMx Default Value**' settings are recommended: For Intertripping schemes set **0**, for Blocking schemes set **1**. In Permissive applications, the user may prefer to latch the last healthy received state

2.16 Phase Fault Overcurrent Protection

Settings for the time delayed overcurrent element should be selected to ensure discrimination with surrounding protection. Setting examples for phase fault overcurrent protection can be found in the Network Protection and Automation Guide (NPAG), a comprehensive reference textbook available from Schneider Electric.

Caution **The IEEE C.37.112 standard for IDMT curves permits some freedom to manufacturers at which Time Dial (TD) value the reference curve applies. Rather than pick a mid-range value, for the MiCOM P443/P446 the reference curve norm applies at a time dial of 1. The TD is merely a multiplier on the reference curve, in order to achieve the desired tripping time. Take care when grading with other suppliers' relays which may take TD = 5, or TD = 7 as a mid-range value to define the IDMT curve. The equivalent MiCOM P443/P446 setting to match those relays is achieved by dividing the imported setting by 5 or 7.**

2.16.1 Directional Overcurrent Characteristic Angle Settings

The relay uses a 90° connection angle for the directional overcurrent elements. The relay characteristic angles in this case are nominally set to:

- +30° Plain feeders, zero sequence source behind relay
- +45° Transformer feeder, zero sequence source in front of relay

Whilst it is possible to set the RCA to exactly match the system fault angle, it is recommended that the above figures are followed, as these settings have been shown to provide satisfactory performance and stability under a wide range of system conditions.

2.17 Thermal Overload Protection

Thermal overload protection can be used to prevent electrical plant from operating at temperatures in excess of the designed maximum withstand. Prolonged overloading causes excessive heating, which may result in premature ageing of the insulation, or in extreme cases, insulation failure.

2.17.1 Single Time Constant Characteristic

The current setting is calculated as:

Thermal Trip = Permissible continuous loading of the plant item/CT ratio.

Typical time constant values are given in the following table. The relay setting, '**Time Constant 1**', is in minutes.

	Time Constant τ (minutes)	**Limits**
Air-core reactors	40	
Capacitor banks	10	
Overhead lines	10	Cross section ≥ 100 mm2 Cu or 150mm2 Al
Cables	60 - 90	Typical, at 66kV and above
Busbars	60	

Table 7 - Typical time constants

An alarm can be raised on reaching a thermal state corresponding to a percentage of the trip threshold. A typical setting might be '**Thermal Alarm**' = 70% of thermal capacity.

2.17.2 Dual Time Constant Characteristic

The current setting is calculated as:

Thermal Trip = Permissible continuous loading of the transformer / CT ratio.

Typical time constants:

	τ1 (minutes)	**τ2 (minutes)**	**Limits**
Oil-filled transformer	5	120	Rating 400 - 1600 kVA

Table 8 - Typical time constants

An alarm can be raised on reaching a thermal state corresponding to a percentage of the trip threshold. A typical setting might be '**Thermal Alarm**' = 70% of thermal capacity.

Note	*The thermal time constants given in the above tables are typical only. Reference should always be made to the plant manufacturer for accurate information.*

Earth Fault (Ground Overcurrent) and Sensitive Earth Fault (SEF) Protection

Caution **The IEEE C.37.112 standard for IDMT curves permits some freedom to manufacturers at which Time Dial (TD) value the reference curve applies. Rather than pick a mid-range value, for the MiCOM P443/P446 the reference curve norm applies at a time dial of 1. The TD is merely a multiplier on the reference curve, in order to achieve the desired tripping time. Take care when grading with other suppliers' relays which may take TD = 5, or TD = 7 as a mid-range value to define the IDMT curve. The equivalent MiCOM P443/P446 setting to match those relays is achieved by dividing the imported setting by 5 or 7.**

2.17.3 Directional Earth Fault Protection

2.17.3.1 Residual Voltage Polarization

It is possible that small levels of residual voltage will be present under normal system conditions due to system imbalances, VT inaccuracies, relay tolerances etc. Hence, the relay includes a user settable threshold (IN>VNPol Set) which must be exceeded in order for the directional earth fault function to be operational. In practice, the typical zero sequence voltage on a healthy system can be as high as 1% (i.e.: 3% residual), and the VT error could be 1% per phase. A setting between 1% and 4% is typical. The residual voltage measurement provided in the "**Measurements**" column of the menu may assist in determining the required threshold setting during commissioning, as this will indicate the level of standing residual voltage present.

2.17.4 General Setting Guidelines for Directional Earth Fault (Ground Overcurrent) Protection

When setting the relay characteristic angle (RCA) for the directional earth fault element, a positive angle setting was specified. This was due to the fact that the quadrature polarizing voltage lagged the nominal phase current by 90°; i.e. the position of the current under fault conditions was leading he polarizing voltage and hence a positive RCA was required. With DEF, the residual current under fault conditions lies at an angle lagging the polarizing voltage. Hence, negative RCA settings are required for DEF applications. This is set in cell '**I>N**' in the relevant earth fault menu.

The following angle settings are recommended for a residual voltage polarized relay:

Distribution systems (solidly earthed)	-45°
Transmissions systems (solidly earthed)	-60°

For negative sequence polarization, the RCA settings must be based on the angle of the upstream negative phase sequence source impedance.

2.17.5 Sensitive Earth Fault (SEF) Protection Element

SEF would normally be fed from a Core Balance Current Transformer (CBCT) mounted around the three phases of the feeder cable. However, care must be taken in the positioning of the CT with respect to the earthing of the cable sheath. See Figure 9.

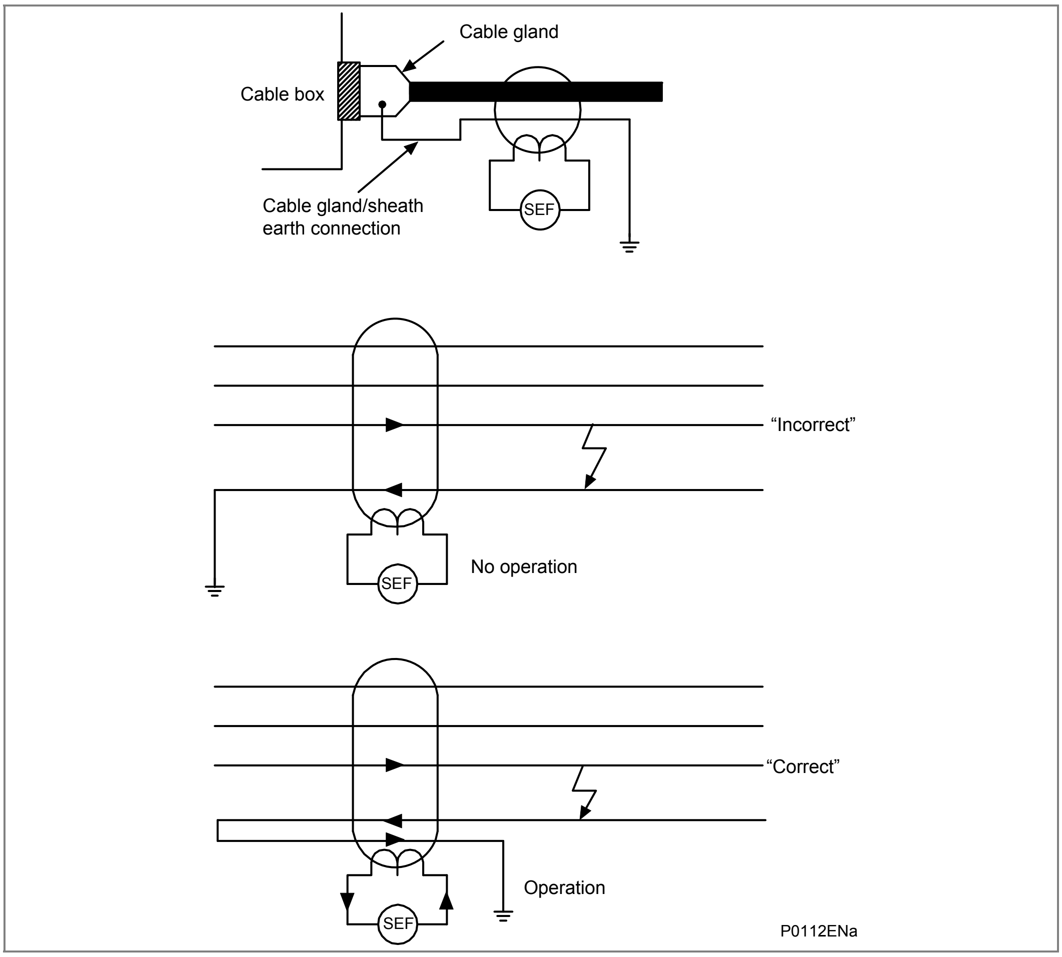


Figure 9 - Positioning of core balance current transformers

As can be seen from Figure 9, if the cable sheath is terminated at the cable gland and earthed directly at that point, a cable fault (from phase to sheath) will not result in any unbalance current in the core balance CT. Hence, prior to earthing, the connection must be brought back through the CBCT and earthed on the feeder side. This then ensures correct relay operation during earth fault conditions.

2.17.6 Restricted Earth Fault Protection

Earth faults occurring on a transformer winding or terminal may be of limited magnitude, either due to the impedance present in the earth path or by the percentage of transformer winding that is involved in the fault. It is common to apply standby earth fault protection fed from a single CT in the transformer earth connection. This provides time-delayed protection for a transformer winding or terminal fault. In general, particularly as the size of the transformer increases, it becomes unacceptable to rely on time delayed protection to clear winding or terminal faults as this would lead to an increased amount of damage to the transformer.

A common requirement is therefore to provide instantaneous phase and earth fault protection. Applying differential protection across the transformer may fulfill these requirements. However, an earth fault occurring on the LV winding, particularly if it is of a limited level, may not be detected by the differential relay, as it is only measuring the corresponding HV current. Therefore, instantaneous protection that is restricted to operating for transformer earth faults only is applied. This is referred to as Restricted Earth Fault (REF) protection.

When applying differential protection such as REF, some suitable means must be employed to give the protection stability under external fault conditions, therefore ensuring that relay operation only occurs for faults on the transformer winding / connections.

Two methods are commonly used; bias or high impedance. The biasing technique operates by measuring the level of through current flowing and altering the relay sensitivity accordingly. The high impedance technique ensures that the relay circuit is of sufficiently high impedance such that the differential voltage that may occur under external fault conditions is less than that required to drive setting current through the relay.

The REF protection in the relays can be configured to operate as high impedance element. Following sections describe the application of the relay for high impedance element.

Note	The high impedance REF element of the relay shares the same CT input as the SEF protection. Hence, only one of these elements may be selected.

2.17.6.1 Setting Guidelines for High Impedance Restricted Earth Fault (REF)

From the **SEF/REF options** cell, **Hi Z REF** must be selected to enable this protection. The only setting cell then visible is **IREF>Is**, which may be programmed with the required differential current setting. This would typically be set to give a primary operating current of either 30% of the minimum earth fault level for a resistance earthed system or between 10 and 60% of rated current for a solidly earthed system.

The primary operating current (Iop) will be a function of the current transformer ratio, the relay operating current (IREF>Is1), the number of current transformers in parallel with a relay element (n) and the magnetizing current of each current transformer (Ie) at the stability voltage (Vs). This relationship can be expressed in three ways:

- To determine the maximum current transformer magnetizing current to achieve a specific primary operating current with a particular relay operating current:
- $I_e < \frac{1}{n} \times \left(\frac{I_{op}}{\text{CT ratio}} - \text{IREF} > \text{Is} \right)$
- To determine the minimum relay current setting to achieve a specific primary operating current with a given current transformer magnetizing current.
- $[\text{IREF} > \text{Is}] < \left(\frac{I_{op}}{\text{CT ratio}} - nI_e \right)$

2.17.6.2 Use of METROSIL Non-Linear Resistors

Metrosils are used to limit the peak voltage developed by the current transformers under internal fault conditions, to a value below the insulation level of the current transformers, relay and interconnecting leads, which are normally able to withstand 3000 V peak.

The following formulae should be used to estimate the peak transient voltage that can be produced for an internal fault. The peak voltage produced during an internal fault will be a function of the current transformer kneepoint voltage and the prospective voltage that would be produced for an internal fault if current transformer saturation did not occur.

$$Vp = 2\sqrt{2V_k(V_f - V_k)}$$

$$Vf = I'f\,(Rct + 2RL + RST)$$

Where:

Vp = Peak voltage developed by the CT under internal fault conditions

Vk = Current transformer kneepoint voltage

Vf = Maximum voltage that would be produced if CT saturation did not occur

I'f = Maximum internal secondary fault current

Rct = Current transformer secondary winding resistance

RL = Maximum lead burden from current transformer to relay

RST = Relay stabilizing resistor

When the value given by the formulae is greater than 3000 V peak, metrosils should be applied. They are connected across the relay circuit and serve the purpose of shunting the secondary current output of the current transformer from the relay in order to prevent very high secondary voltages.

Metrosils are externally mounted and take the form of annular discs. Their operating characteristics follow the expression:

$$V = CI^{0.25}$$

Where:

V = Instantaneous voltage applied to the non-linear resistor (metrosil)

C = Constant of the non-linear resistor (metrosil)

I = Instantaneous current through the non-linear resistor (metrosil)

With a sinusoidal voltage applied across the metrosil, the RMS current would be approximately 0.52 x the peak current. This current value can be calculated as follows:

$$I(rms) = 0.52 \left(\frac{Vs\ (rms) \times \sqrt{2}}{C} \right)^4$$

Where:

Vs(rms) = rms value of the sinusoidal voltage applied across the metrosil.

This is due to the fact that the current waveform through the metrosil is not sinusoidal but appreciably distorted.

For satisfactory application of a non-linear resistor (Metrosil), its characteristic should be such that it complies with the following requirements:

- At the relay voltage setting, the non-linear resistor (Metrosil) current should be as low as possible, but no greater than approximately 30 mA rms for 1 A current transformers and approximately 100 mA rms for 5 A current transformers.
- At the maximum secondary current, the non-linear resistor (Metrosil) should limit the voltage to 1500 V rms or 2120 V peak for 0.25 second. At higher relay voltage settings, it is not always possible to limit the fault voltage to 1500V rms, so higher fault voltages may have to be tolerated.

The following tables show the typical Metrosil types that will be required, depending on relay current rating, REF voltage setting etc.

Metrosil Units for Relays with a 1 Amp CT

The Metrosil units with 1 Amp CTs have been designed to comply with the following restrictions:

- At the relay voltage setting, the Metrosil current should be less than 30 mA rms.
- At the maximum secondary internal fault current the Metrosil unit should limit the voltage to 1500 V rms if possible.

The Metrosil units normally recommended for use with 1 Amp CTs are as shown in the following table:

Relay voltage setting	Nominal characteristic		Recommended Metrosil type	
	C	**β**	**Single pole relay**	**Triple pole relay**
Up to 125 V rms	450	0.25	600A/S1/S256	600A/S3/1/S802
125 to 300 V rms	900	0.25	600A/S1/S1088	600A/S3/1/S1195

Note *Single pole Metrosil units are normally supplied without mounting brackets unless otherwise specified by the customer.*

Table 9 - Metrosil units normally recommended for use with 1 Amp CTs

Metrosil units for relays with a 5 amp CT

These Metrosil units have been designed to comply with the following requirements:

- At the relay voltage setting, the Metrosil current should be less than 100mA rms (the actual maximum currents passed by the units shown below their type description.
- At the maximum secondary internal fault current the Metrosil unit should limit the voltage to 1500V rms for 0.25 secs. At the higher relay settings, it is not possible to limit the fault voltage to 1500 V rms hence higher fault voltages have to be tolerated (indicated by *, **, ***).
- The Metrosil units normally recommended for use with 5 Amp CTs and single pole relays are as shown in the following table:

Secondary internal fault current	Recommended Metrosil type			
	Relay voltage setting			
Amps rms	**Up to 200 V rms**	**250 V rms**	**275 V rms**	**300 V rms**
50 A	600A/S1/S1213 C = 540/640 35 mA rms	600A/S1/S1214 C = 670/800 40 mA rms	600A/S1/S1214 C =670/800 50 mA rms	600A/S1/S1223 C = 740/870* 50 mA rms
100 A	600A/S2/P/S1217 C = 470/540 70 mA rms	600A/S2/P/S1215 C = 570/670 75 mA rms	600A/S2/P/S1215 C =570/670 100 mA rms	600A/S2/P/S1196 C =620/740* 100 mA rms
150 A	600A/S3/P/S1219 C = 430/500 100 mA rms	600A/S3/P/S1220 C = 520/620 100 mA rms	600A/S3/P/S1221C = 570/670** 100 mA rms	600A/S3/P/S1222C =620/740*** 100 mA rms
	Notes	*2400 V peak	**2200 V peak	***2600 V peak

Table 10 - Metrosil units normally recommended for use with 5 Amp CTs

In some situations single disc assemblies may be acceptable, contact Schneider Electric for detailed applications.

Note *The Metrosil units recommended for use with 5 Amp CTs can also be applied for use with triple pole relays and consist of three single pole units mounted on the same central stud but electrically insulated from each other. To order these units please specify "**Triple pole Metrosil type**", followed by the single pole type reference.*
Metrosil units for higher relay voltage settings and fault currents can be supplied if required.
To express the protection primary operating current for a particular relay operating current and with a particular level of magnetizing current.

I_{op} = (CT ratio) x (IREF > Is + nI_C)

To achieve the required primary operating current with the current transformers that are used, a current setting (IREF>Is) must be selected for the high impedance element, as detailed in expression (ii) above. The setting of the Stabilizing Resistor (RST) must be calculated in the following manner, where the setting is a function of the required stability voltage setting (Vs) and the relay current setting (IREF>Is).

$$R_{st} = \frac{Vs}{I_{REF}>Is} = \frac{I_F\ (R_{CT} + 2_{RL})}{I_{REF} > I_s}$$

Note	The above formula assumes negligible relay burden.

The stabilizing resistor that can be supplied is continuously adjustable up to its maximum declared resistance.

2.18 Negative Phase Sequence (NPS) Overcurrent Protection

The following section describes how negative phase sequence overcurrent protection may be applied in conjunction with standard overcurrent and earth fault protection in order to alleviate some less common application difficulties:

- Negative phase sequence overcurrent elements give greater sensitivity to resistive phase-to-phase faults, where phase overcurrent elements may not operate.
- In certain applications, residual current may not be detected by an earth fault relay due to the system configuration. For example, an earth fault relay applied on the delta side of a Dy (delta-wye) transformer is unable to detect earth faults on the star (wye) side. However, negative sequence current will be present on both sides of the transformer for any fault condition, irrespective of the transformer configuration. Therefore, a negative phase sequence overcurrent element may be employed to provide time-delayed back-up protection for any uncleared asymmetrical faults downstream.
- It may be required to simply alarm for the presence of negative phase sequence currents on the system. Operators may then investigate the cause of the unbalance.

2.18.1 Negative Phase Sequence Current Threshold, 'I2> Current Set'

The current pick-up threshold must be set higher than the negative phase sequence current due to the maximum normal load unbalance on the system. This can be set practically at the commissioning stage, making use of the relay measurement function to display the standing negative phase sequence current, and setting at least 20% above this figure.

Where the negative phase sequence element is required to operate for specific uncleared asymmetric faults, a precise threshold setting would have to be based upon an individual fault analysis for that particular system due to the complexities involved. However, to ensure operation of the protection, the current pick-up setting must be set approximately 20% below the lowest calculated negative phase sequence fault current contribution to a specific remote fault condition.

2.18.2 Time Delay for the NPS Overcurrent Element, ‘I2> Time Delay’

As stated above, correct setting of the time delay for this function is vital. It should also be noted that this element is applied primarily to provide back-up protection to other protective devices or to provide an alarm. Hence, in practice, it would be associated with a long time delay.

It must be ensured that the time delay is set greater than the operating time of any other protective device (at minimum fault level) on the system which may respond to unbalanced faults.

2.18.3 Directionalizing the Negative Phase Sequence Overcurrent Element

Where negative phase sequence current may flow in either direction through a relay location, such as parallel lines, directional control of the element should be employed. Directionality is achieved by comparison of the angle between the negative phase sequence voltage and the negative phase sequence current and the element may be selected to operate in either the forward or reverse direction. A suitable relay characteristic angle setting (I2> Char Angle) is chosen to provide optimum performance. This setting should be set equal to the phase angle of the negative sequence current with respect to the inverted negative sequence voltage (– V2), in order to be at the center of the directional characteristic.

The angle that occurs between V2 and I2 under fault conditions is directly dependent upon the negative sequence source impedance of the system. However, typical settings for the element are as follows;

- For a transmission system the RCA should be set equal to -60°
- For a distribution system the RCA should be set equal to -45°

For the negative phase sequence directional elements to operate, the relay must detect a polarizing voltage above a minimum threshold, "**I2> V2pol Set**". This must be set in excess of any steady state negative phase sequence voltage. This may be determined during the commissioning stage by viewing the negative phase sequence measurements in the relay.

2.19 Undervoltage Protection

In the majority of applications, undervoltage protection is not required to operate during system earth (ground) fault conditions. If this is the case, the element should be selected in the menu to operate from a phase to phase voltage measurement, as this quantity is less affected by single phase voltage depressions due to earth faults. The measuring mode (ph-N or ph-ph) and operating mode (single phase or 3 phase) for both stages are independently settable.

The voltage threshold setting for the undervoltage protection should be set at some value below the voltage excursions which may be expected under normal system operating conditions. This threshold is dependent upon the system in question but typical healthy system voltage excursions may be in the order of -10% of nominal value.

Similar comments apply with regard to a time setting for this element, i.e. the required time delay is dependent upon the time for which the system is able to withstand a depressed voltage.

2.20 Overvoltage Protection

The inclusion of the two stages and their respective operating characteristics allows for a number of possible applications;

- Use of the IDMT characteristic gives the option of a longer time delay if the overvoltage condition is only slight but results in a fast trip for a severe overvoltage. As the voltage settings for both of the stages are independent, the second stage could then be set lower than the first to provide a time delayed alarm stage if required.
- Alternatively, if preferred, both stages could be set to definite time and configured to provide the required alarm and trip stages.

- If only one stage of overvoltage protection is required, or if the element is required to provide an alarm only, the remaining stage may be disabled within the relay menu.

This type of protection must be co-ordinated with any other overvoltage relays at other locations on the system. This should be carried out in a similar manner to that used for grading current operated devices. The measuring mode (ph-N or ph-ph) and operating mode (single-phase or 3-phase) for both stages are independently settable.

2.21 Compensated Overvoltage Protection

Temporary overvoltages in the order of seconds (even minutes) which may originate from switching or load rejection may damage primary plant equipment. In particular, this type of overvoltage protection is applied to protect long transmission lines against Ferranti effect overvoltages where the transmission line is energized from one end only. Figure 10 shows the Ferranti overvoltages calculated for a 345kV and 765kV transmission line for different line lengths based on the formulas as in section (P44y/EN OP).

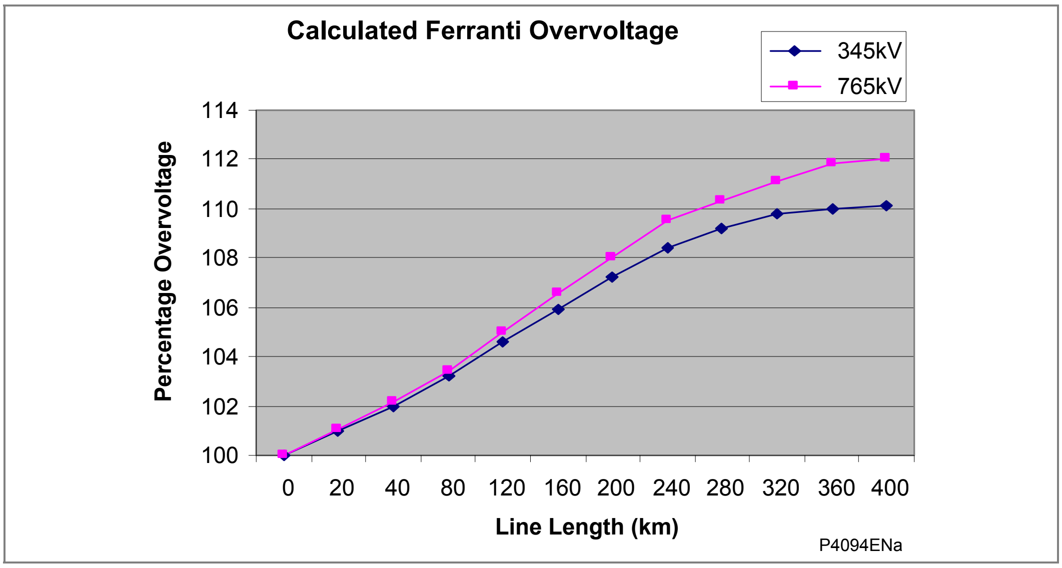


Figure 10 - Calculated Ferranti voltage rise on 345kV and 765kV lines

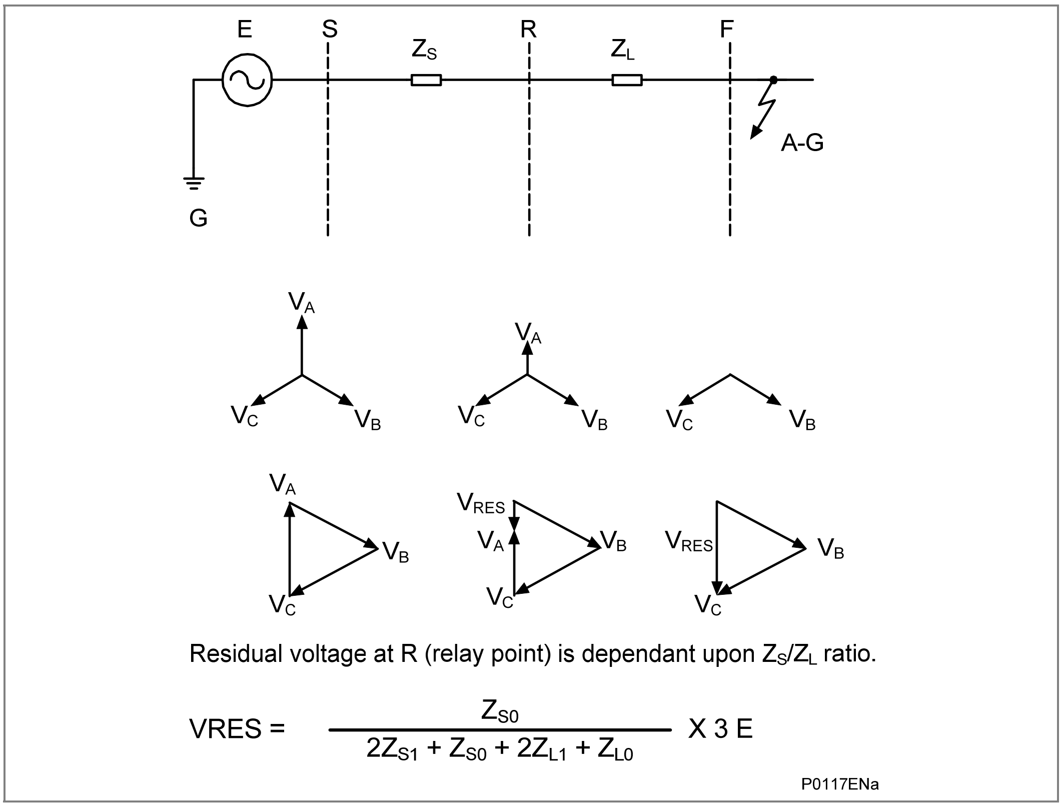
The two stage compensated overvoltage element can be applied as alarming or trip elements. Both stages' time delays should be set not to pick-up for transient overvoltages in the system with a typical time delays of 1-2 seconds upwards being adequate for most applications. In the example above for a 345kV transmission line of 400km line length, the alarm threshold (stage 1) can be set to 105% and the trip threshold set to 110% for example.

2.22 Residual Overvoltage (Neutral Displacement) Protection

On a healthy three phase power system, the addition of each of the three phase to earth voltages is nominally zero, as it is the vector addition of three balanced vectors at 120° to one another. However, when an earth (ground) fault occurs on the primary system this balance is upset and a ‘**residual**’ voltage is produced.

> *Note* *This condition causes a rise in the neutral voltage with respect to earth which is commonly referred to as “**neutral voltage displacement**” or NVD.*

Figure 11 and Figure 12 show the residual voltages that are produced during earth fault conditions occurring on a solid and impedance earthed power system respectively.



Residual voltage at R (relay point) is dependant upon Z_S/Z_L ratio.

$$\text{VRES} = \frac{Z_{S0}}{2Z_{S1} + Z_{S0} + 2Z_{L1} + Z_{L0}} \times 3\text{E}$$

Figure 11 - Residual voltage, solidly earthed system

As can be seen in Figure 11 the residual voltage measured by a relay for an earth fault on a solidly earthed system is solely dependent upon the ratio of source impedance behind the relay to line impedance in front of the relay, up to the point of fault. For a remote fault, the Zs/Zl ratio will be small, resulting in a correspondingly small residual voltage. As such, depending upon the relay setting, such a relay would only operate for faults up to a certain distance along the system. The value of residual voltage generated for an earth fault condition is given by the general formula shown.

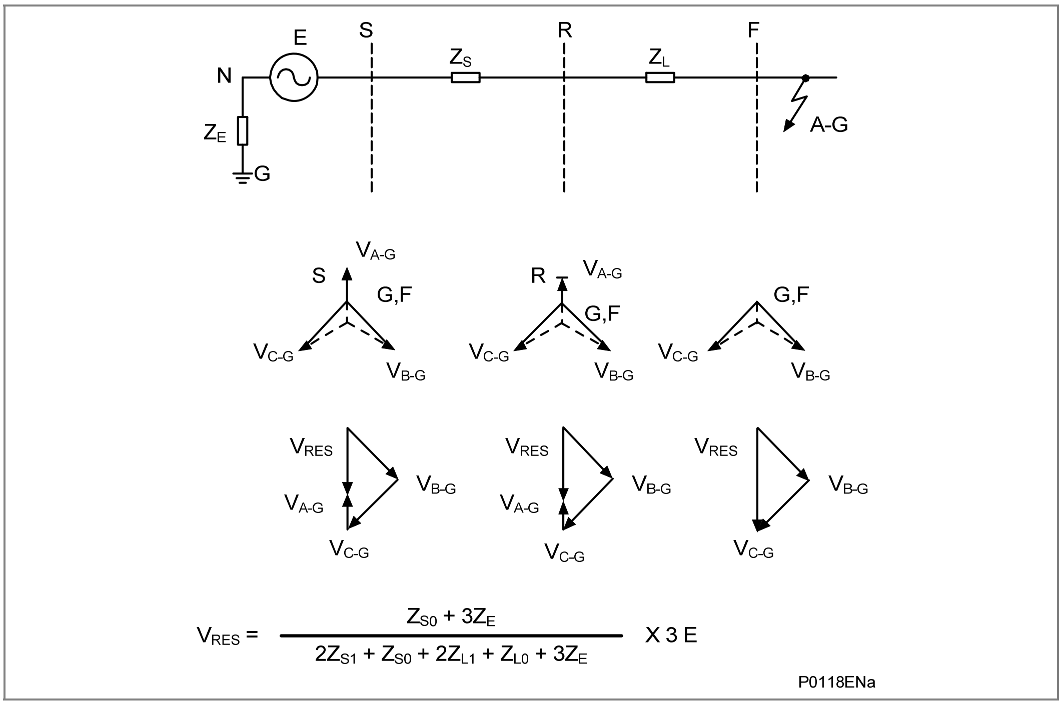


Figure 12 - Residual voltage, resistance earthed system

Figure 12 shows that a resistance earthed system will always generate a relatively large degree of residual voltage, as the zero sequence source impedance now includes the earthing impedance. It follows then, that the residual voltage generated by an earth fault on an insulated system will be the highest possible value (3 x phase-neutral voltage), as the zero sequence source impedance is infinite.

From the above information it can be seen that the detection of a residual overvoltage condition is an alternative means of earth fault detection, which does not require any measurement of zero sequence current. This may be particularly advantageous at a tee terminal where the infeed is from a delta winding of a transformer (and the delta acts as a zero sequence current trap).

It must be noted that where residual overvoltage protection is applied, such a voltage will be generated for a fault occurring anywhere on that section of the system and hence the NVD protection must co-ordinate with other earth/ground fault protection.

2.22.1 Setting Guidelines

The voltage setting applied to the elements is dependent upon the magnitude of residual voltage that is expected to occur during the earth fault condition. This in turn is dependent upon the method of system earthing employed and may be calculated by using the formulae previously given in Figures 11 and 12. It must also be ensured that the relay is set above any standing level of residual voltage that is present on the system.

Note	*IDMT characteristics are selectable on the first stage of NVD in order that elements located at various points on the system may be time graded with one another.*

2.23 Circuit Breaker Fail Protection (CBF)

2.23.1 Breaker Fail Timer Settings

Typical timer settings to use are as follows:

CB Fail Reset Mechanism	tBF Time Delay	Typical Delay for 2 ½ Cycle Circuit Breaker
Initiating element reset	CB interrupting time + element reset time (max.) + error in tBF timer + safety margin	50 + 45 + 10 + 50 = 155 ms
CB open	CB auxiliary contacts opening/closing time (max.) + error in tBF timer + safety margin	50 + 10 + 50 = 110 ms
Undercurrent elements	CB interrupting time + undercurrent element (max.) + safety margin	50 + 25 + 50 = 125 ms

Note *All CB Fail resetting involves the operation of the undercurrent elements. Where element reset or CB open resetting is used the undercurrent time setting should still be used if this proves to be the worst case.*

The examples above consider direct tripping of a 2½ cycle circuit breaker.

Note *Where auxiliary tripping relays are used, an additional 10-15 ms must be added to allow for trip relay operation.*

Table 11 - Typical timer settings

2.23.2 Breaker Fail Undercurrent Settings

The phase undercurrent settings (I<) must be set less than load current, to ensure that I< operation indicates that the circuit breaker pole is open. A typical setting for overhead line or cable circuits is 20% In, reduced to 10% or 5% where the infeed has a high SIR ratio (e.g. at a spur terminal with embedded generation infeed).

The Sensitive Earth Fault protection (SEF) undercurrent element must be set less than the respective trip setting, typically as follows:

ISEF< = (ISEF> trip) / 2

2.24 Broken Conductor Detection

The majority of faults on a power system occur between one phase and ground or two phases and ground. These are known as shunt faults and arise from lightning discharges and other overvoltages which initiate flashovers. Alternatively, they may arise from other causes such as birds on overhead lines or mechanical damage to cables etc. Such faults result in an appreciable increase in current and hence in the majority of applications are easily detectable.

Another type of unbalanced fault that can occur on the system is the series or open circuit fault. These can arise from broken conductors, mal-operation of single phase switchgear, or single-phasing of fuses. Series faults will not cause an increase in phase current on the system and hence are not readily detectable by standard protection. However, they will produce an unbalance and a resultant level of negative phase sequence current, which can be detected.

It is possible to apply a negative phase sequence overcurrent relay to detect the above condition. However, on a lightly loaded line, the negative sequence current resulting from a series fault condition may be very close to, or less than, the full load steady state unbalance arising from CT errors, load unbalance etc. A negative sequence element therefore would not operate at low load levels.

2.24.1 Setting Guidelines

For a broken conductor affecting a single point earthed power system, there will be little zero sequence current flow and the ratio of I2/I1 that flows in the protected circuit will approach 100%. In the case of a multiple earthed power system (assuming equal impedance's in each sequence network), the ratio I2/I1 will be 50%.

In practice, the levels of standing negative phase sequence current present on the system govern this minimum setting. This can be determined from a system study, or by making use of the relay measurement facilities at the commissioning stage. If the latter method is adopted, it is important to take the measurements during maximum system load conditions, to ensure that all single-phase loads are accounted for.

Note	*A minimum value of 8% negative phase sequence current is required for successful relay operation.*

Since sensitive settings have been employed, it can be expected that the element will operate for any unbalance condition occurring on the system (for example, during a single pole auto-reclose cycle). Hence, a long time delay is necessary to ensure co-ordination with other protective devices. A 60 second time delay setting may be typical.

The example following information was recorded by the relay during commissioning;

Ifull load = 500 A

I2 = 50 A

therefore the quiescent I2/I1 ratio is given by;

I2/I1 = 50/500 = 0.1

To allow for tolerances and load variations a setting of 20% of this value may be typical: Therefore set I2/I1 = 0.2

In a double circuit (parallel line) application, using a 40% setting will ensure that the broken conductor protection will operate only for the circuit that is affected. Setting 0.4 results in no pick-up for the parallel healthy circuit.

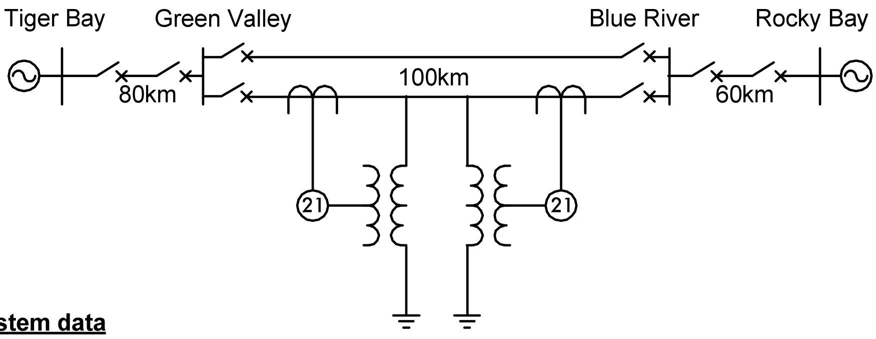
Set I2/I1 Time Delay = 60s to allow adequate time for short circuit fault clearance by time delayed protections.

3 WORKED PROTECTION EXAMPLE AND OTHER TIPS

3.1 Distance Protection Setting Example

3.1.1 Objective

To protect the 100km double circuit line between Green Valley and Blue River substations using a MiCOM P443/P446 in distance POR Permissive Overreach mode and to set the relay at Green Valley substation, shown in Figure 13. It is assumed that mho characteristics will be used.



System data

Green Valley – Blue River transmission line
System voltage 230kv
System grounding solid
CT ratio 1200/5
VT ratio 230000/115
Line length 100km
Line impedance
Z1 = 0.089 + J0.476 OHM/km
Z2 = 0.426 + J1.576 OHM/km
Fault levels
Green Valley substation busbars maximum 5000MVA, minimum 2000MVA
Blue River substation busbars maximum 3000MVA, minimum 1000MVA
Circuit continuous rating = 400MVA
Worst-case power factor of load = 0.85

P1019ENb

Figure 13 - System assumed for worked example

3.1.2 System Data

Line length: 100km

Line impedances: Z_1 = $0.089 + j0.476 = 0.484 \angle 79.4° \Omega/km$

Z_0 = $0.426 + j1.576 = 1.632 \angle 74.8° \Omega/km$

Z_0/Z_1 = $3.372 \angle -4.6°$

CT ratio: 1 200/5

VT ratio: 230 000/115

3.1.3 Relay Settings

It is assumed that Zone 1 Extension is not used and that only three forward zones are required. Settings on the relay can be performed in primary or secondary quantities and impedances can be expressed as either polar or rectangular quantities (menu selectable). For the purposes of this example, secondary quantities are used.

3.1.4 Line Impedance

Ratio of secondary to primary impedance = $\frac{1200 / 5}{230000 / 115}$ = 0.12

Line impedance secondary = ratio CT/VT x line impedance primary.

Line Impedance

= $100 \times 0.484 \angle 79.4°$ (primary) x 0.124

= $5.81 \angle 79.4°\ \Omega$ secondary.

Select line angle = 80° for convenience.

Therefore set line impedance and line angle: = $5.81 \angle 80°\ \Omega$ secondary.

3.1.5 Residual Compensation for Ground Fault Elements

The residual compensation factor can be applied independently to certain zones if required. This feature is useful where line impedance characteristics change between sections or where hybrid circuits are used. In this example, the line impedance characteristics do not change and as such a common KZN factor can be applied to each zone. This is set as a ratio “**kZN Res. Comp**”, and an angle “**kZN Angle**”:

kZN Res. Comp, $|kZN|$ = (Z0 - Z1) / 3Z1 i.e.: As a ratio

kZN Angle, $\angle kZN$ = $\angle$ (Z0 - Z1) / 3Z1 Set in degrees

ZL0 - ZL1 = (0.426 + j1.576) - (0.089 + j0.476)

= 0.337 + j1.1

= $1.15 \angle 72.9°$

$$kZN = \frac{1.15\angle 72.9°}{3 \times 0.484\angle 79.4°} = 0.79 \angle{-6.5°}$$

Therefore, select:

kZN Res. Comp = 0.7

kZN Angle = - 6.5°

3.1.6 Zone 1 Phase and Ground Reach Settings

Required Zone 1 reach is to be 80% of the line impedance between Green Valley and Blue River substations.

Setting the Relay in the SIMPLE setting mode (recommended):

Set Zone 1 Ph and Zone 1 Gnd reach = 80%

From this the relay will automatically calculate the required ohmic reaches, or they can be entered manually in the ADVANCED mode, as follows:

Required Zone 1 reach = 0.8 x 100 x 0.484 $\angle 79.4^\circ$ x 0.12

Z1 = 4.64 $\angle 79.4^\circ$ Ω secondary

The Line Angle = 80°

Therefore actual Zone 1 reach, Z1 = 4.64 $\angle 80^\circ$ Ω secondary.

3.1.7 Zone 2 Phase and Ground Reach Settings

Required Zone 2 impedance = (Green Valley-Blue River) line impedance + 50% (Blue River-Rocky Bay) line impedance

Z2 = (100+30) x 0.484 $\angle 79.4^\circ$ x 0.12 = 7.56 $\angle 79.4^\circ$ Ω secondary.

The Line Angle = 80°

Actual Zone 2 reach setting = 7.56 $\angle 80^\circ$ Ω secondary

Alternatively, in SIMPLE setting mode, this reach can be set as a percentage of the protected line. Typically a figure of at least 120% is used.

3.1.8 Zone 3 Phase and Ground Reach Settings

Required Zone 3 forward reach = (Green Valley-Blue River + Blue River-Rocky Bay) x 1.2

= (100+60) x 1.2 x 0.484 $\angle 79.4^\circ$ x 0.12

Z3 = 11.15 $\angle 79.4^\circ$ ohms secondary

Actual Zone 3 forward reach setting = 11.16 $\angle 80^\circ$ ohms secondary

Alternatively, in SIMPLE setting mode, this reach can be set as a percentage of the protected line.

3.1.9 Zone 3 Reverse Reach

In the absence of other special requirements, Zone 3 can be given a small reverse reach setting, of Z3' = 10%. This is acceptable because the protected line length is > 30km.

Zone 4 Reverse Settings with POR and BLOCKING schemes

Where zone 4 is used to provide reverse directional decisions for Blocking or Permissive Overreach schemes, zone 4 must reach further behind the relay than zone 2 for the remote relay. This can be achieved by setting: $Z4 \geq$ ((Remote zone 2 reach) x 120%), where mho characteristics are used.

Remote Zone 2 reach = (Blue River-Green Valley) line impedance + 50% (Green Valley-Tiger Bay) line impedance

$= (100+40) \times 0.484 \angle 79.4^\circ \times 0.12$

$= 8.13 \angle 79.4^\circ\ \Omega$ secondary

$Z4 \geq ((8.13 \angle 79.4^\circ) \times 120\%) - (5.81 \angle 79.4^\circ)$

$= 3.95 \angle 79.4^\circ$

Minimum zone 4 reverse reach setting = $3.96 \angle 80^\circ$ ohms secondary

3.1.10 Load Avoidance

The maximum full load current of the line can be determined from the calculation:

$I_{FLC} = [(\text{Rated MVA}_{FLC}) / (\sqrt{3} \times \text{Line kV})]$

In practice, relay settings must allow for a level of overloading, typically a maximum current of 120% IFLC prevailing on the system transmission lines. Also, for a double circuit line, during the auto-reclose dead time of fault clearance on the adjacent circuit, twice this level of current may flow on the healthy line for a short period of time. Thus, the circuit current loading could be 2.4 x IFLC.

With such a heavy load flow, the system voltage may be depressed, typically with phase voltages down to 90% of Vn nominal.

Allowing for a tolerance in the measuring circuit inputs (line CT error, VT error, relay tolerance, and safety margin), this results in a load impedance which might be 3 times the expected "**rating**".

To avoid the load, the blinder impedance needs to be set:

$Z \leq$ (Rated phase-ground voltage Vn) / (IFLC x 3)

$= (115/\sqrt{3}) / (\text{IFLC} \times 3)$

Set the V< Blinder voltage threshold at the recommended 70% of Vn = 66.4 x 0.7 = 45V.

3.1.11 Additional Settings for Quadrilateral Applications

3.1.11.1 Phase Fault Resistive Reaches (Rph)

In primary impedance terms, RPh reaches must be set to cover the maximum expected phase-to-phase fault resistance. Ideally, RPh must be set greater than the maximum fault arc resistance for a phase-phase fault, calculated as follows:

Ra = (28710 x L)/If $^{1.4}$

Where:

If = Minimum expected phase-phase fault current (A);

L = Maximum phase conductor separation (m);

Ra = Arc resistance, calculated from the van Warrington formula (Ω).

Typical figures for Ra (primary Ω) are given in the table below, for different values of minimum expected phase fault current.

Conductor Spacing (m)	Typical System Voltage (kV)	If = 1kA	If = 2kA	If = 3kA
4	110 - 132	7.2Ω	2.8Ω	1.6Ω
8	220 - 275	14.5Ω	5.5Ω	3.1Ω
11	380 - 400	19.9Ω	7.6Ω	4.3Ω

Note *Dual-end infeed effects will make a fault resistance appear higher, because each relay cannot measure the current contribution from the remote line end. The apparent fault resistance increase factor could be 2 to 8 times the calculated resistance. Therefore it is recommended that the Zone resistive reaches are set to say, 4 times the primary arc resistance calculation.*

Table 12 - Typical figures for Ra

In the example, the minimum phase fault level is 1000MVA. This is equivalent to an effective short-circuit fault feeding impedance of:

Z = kV 2/MVA = 2302/1000 = 53Ω (primary)

The lowest phase fault current level is equivalent to:

Ifault = (MVA x 1000)/(√3 x kV)

= (1000 x 1000)/(√3 x 230)

= 2.5kA

And this fault current in the van Warrington formula would give an arc resistance of:

Ra = 4Ω

As this impedance is relatively small compared to the value “**Z**” calculated above, there is no need to perform an iterative equation to work out the actual expected Ifault (which would in reality be lower due to the added Ra arc resistance in the fault loop). It will suffice to increase the calculated Ra by the recommended factor of four, and a little extra to account for the fault current being lower than that calculated. So in this case use a minimum setting of 5 x Ra, which is 20Ω primary.

It is obvious that the setting could easily be set above 20Ω on the primary system (perhaps following the rule of thumb formula in section 2.5). Typically, all zone resistive reaches would be set greater than this 20Ω primary figure, and ideally less than the load impedance (see “**load avoidance**” section).

3.1.11.2 Ground Fault Resistive Reaches (RGnd)

Fault resistance would comprise arc-resistance and tower footing resistance. A typical resistive reach coverage setting would be 40Ω on the primary system.

For high resistance earth faults, the situation may arise where no distance elements could operate. In this case it will be necessary to provide supplementary earth fault protection, for example using the relay Channel Aided DEF protection. In such cases it is not essential to set large resistive reaches for ground distance, and then RGnd can be set according to the rule of thumb formula in section 2.6.

3.2 Teed Feeder Protection

The application of distance relays to three terminal lines is fairly common. However, several problems arise when applying distance protection to three terminal lines.

3.2.1 The Apparent Impedance seen by the Distance Elements

Figure 14 shows a typical three terminal line arrangement. For a fault at the busbars of terminal B the impedance seen by a relay at terminal A will be equal to:

$$Za = Zat + Zbt + [Zbt.(Ic/Ia)]$$

Relay A will underreach for faults beyond the tee-point with infeed from terminal C. When terminal C is a relatively strong source, the underreaching effect can be substantial. For a zone 2 element set to 120% of the protected line, this effect may result in non-operation of the element for internal faults. This not only effects time delayed zone 2 tripping but also channel-aided schemes. Where infeed is present, it will be necessary for Zone 2 elements at all line terminals to overreach both remote terminals with allowance for the effect of tee-point infeed. Zone 1 elements must be set to underreach the true impedance to the nearest terminal without infeed. Both these requirements can be met through use of the alternative setting groups.

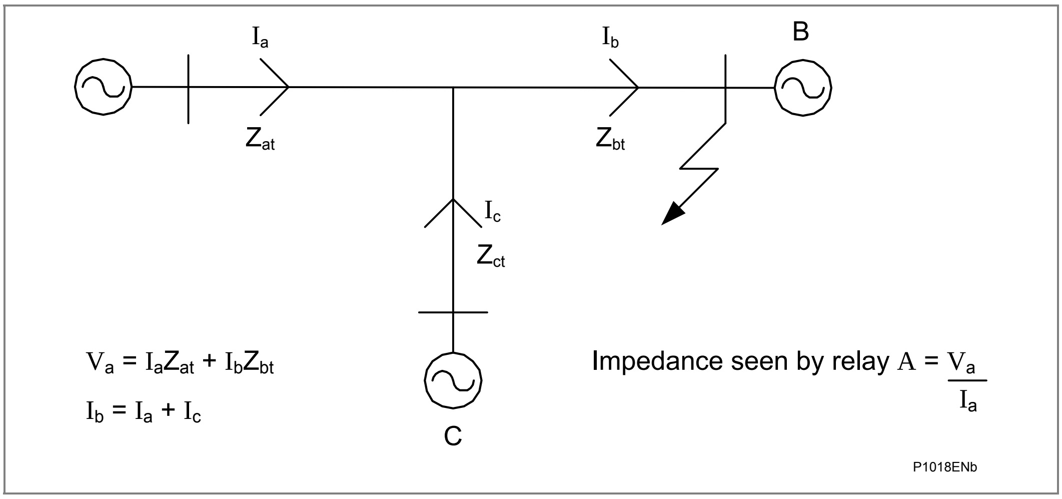

I_a
I_b
B
Z_{at}
Z_{bt}
I_c
Z_{ct}
$V_a = I_aZ_{at} + I_bZ_{bt}$
$I_b = I_a + I_c$
C
Impedance seen by relay A = $\frac{V_a}{I_a}$
P1018ENb

Figure 14 - Teed feeder application - apparent impedances seen by relay

3.2.2 Permissive Overreach Schemes

To ensure operation for internal faults in a POR scheme, the relays at the three terminals should be able to see a fault at any point within the protected feeder. This may demand very large zone 2 reach settings to deal with the apparent impedances seen by the relays.

A POR scheme requires the use of two signaling channels. A permissive trip can only be issued upon operation of zone 2 and receipt of a signal from both remote line ends. The requirement for an '**AND**' function of received signals must be realized through use of contact logic external to the relay, or the internal Programmable Scheme Logic. Although a POR scheme can be applied to a three terminal line, the signaling requirements make its use unattractive.

3.2.3 Permissive Underreach Schemes

For a PUR scheme, the signaling channel is only keyed for internal faults. Permissive tripping is allowed for operation of zone 2 plus receipt of a signal from either remote line end. This makes the signaling channel requirements for a PUR scheme less demanding than for a POR scheme. A common Power Line Carrier (PLC) signaling channel or a triangulated signaling arrangement can be used. This makes the use of a PUR scheme for a teed feeder a more attractive alternative than use of a POR scheme.

The channel is keyed from operation of zone 1 tripping elements. Provided at least one zone 1 element can see an internal fault then aided tripping will occur at the other terminals if the overreaching zone 2 setting requirement has been met. There are however two cases where this is not possible:

- Figure 15 (i) shows the case where a short tee is connected close to another terminal. In this case, zone 1 elements set to 80% of the shortest relative feeder length do not overlap. This leaves a section not covered by any zone 1 element. Any fault in this section would result in zone 2 time delayed tripping.
- Figure 15 (ii) shows an example where terminal '**C**' has no infeed. Faults close to this terminal will not operate the relay at '**C**' and hence the fault will be cleared by the zone 2 time-delayed elements of the relays at '**A**' and '**B**'.

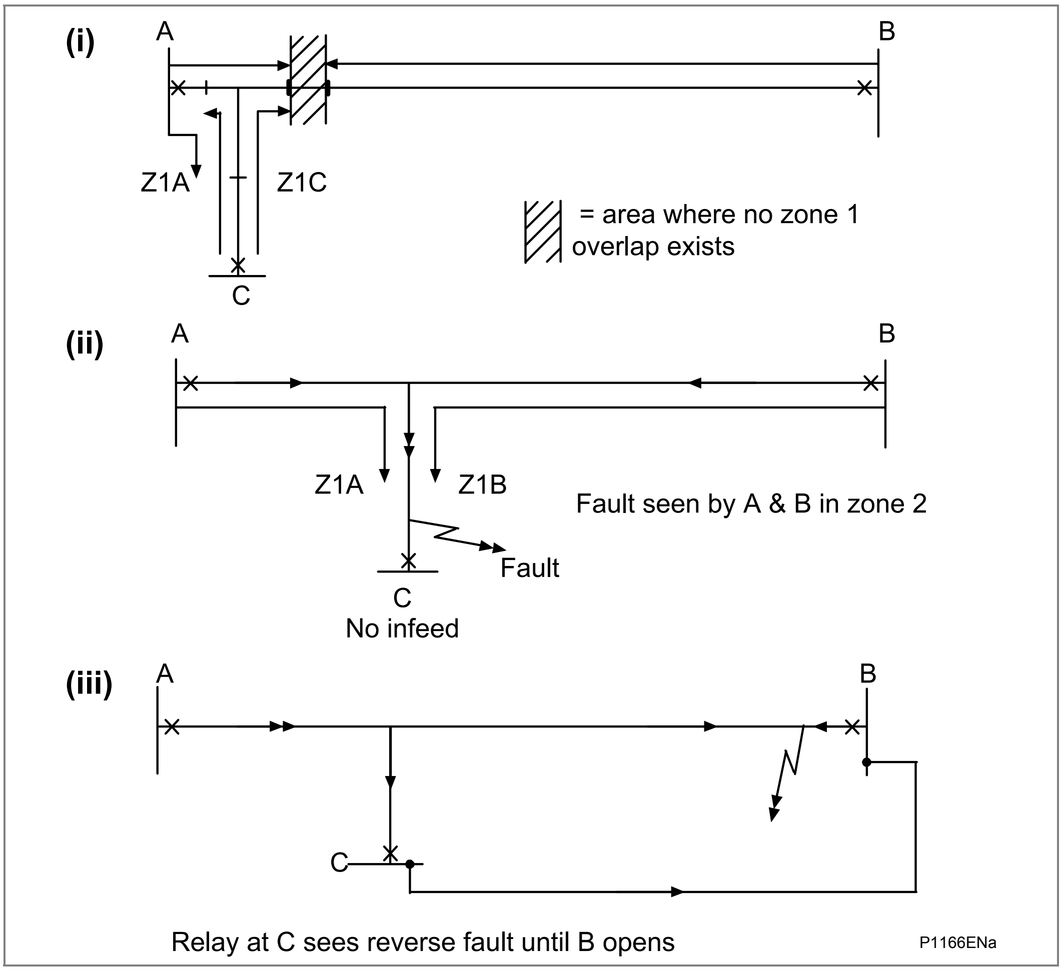

(i)
A
B
Z1A
Z1C
C
= area where no zone 1 overlap exists
(ii)
A
B
Z1A
Z1B
Fault seen by A & B in zone 2
Fault
C
No infeed
(iii)
A
B
C
Relay at C sees reverse fault until B opens
P1166ENa

Figure 15 - Teed feeder applications

- Figure 15 (iii) illustrates a further difficulty for a PUR scheme. In this example current is outfed from terminal '**C**' for an internal fault. The relay at '**C**' will therefore see the fault as reverse and not operate until the breaker at '**B**' has opened; i.e. sequential tripping will occur.

3.2.4 Blocking Schemes

Blocking schemes are particularly suited to the protection of teed feeders, since high speed operation can be achieved where there is no current infeed from one or more terminals. The scheme also has the advantage that only a common simplex channel or a triangulated simplex channel is required.

The major disadvantage of blocking schemes is highlighted in Figure 15 (iii) where fault current is outfed from a terminal for an internal fault condition. Relay '**C**' sees a reverse fault condition. This results in a blocking signal being sent to the two remote line ends, preventing tripping until the normal zone 2 time delay has expired.

3.3 VT Connections

3.3.1 Open Delta (Vee-Connected) VT's

The MiCOM P443 relay can be used with vee-connected VTs by connecting the VT secondaries to C19, C20 and C21 input terminals, with the C22 input left unconnected (for P446, terminals D19 - D22 would apply).

This type of VT arrangement cannot pass zero-sequence (residual) voltage to the relay, or provide any phase to neutral voltage quantities. Therefore any protection that is dependent upon phase to neutral voltage measurements should be disabled.

The ground directional comparison elements, ground distance elements, neutral voltage displacement (residual overvoltage) and CT supervision all use phase-to-neutral voltage signals for their operation and should be disabled. The DEF elements should be selected for negative sequence polarization to avoid the use of phase-to-neutral voltages. Under and over voltage protection can be set as phase-to-phase measuring elements, whereas all other protection elements should remain operational.

The accuracy of the single phase voltage measurements can be impaired when using vee-connected VT's. The relay attempts to derive the phase to neutral voltages from the phase to phase voltage vectors. If the impedance of the voltage inputs were perfectly matched the phase to neutral voltage measurements would be correct, provided the phase to phase voltage vectors were balanced. However, in practice there are small differences in the impedance of the voltage inputs, which can cause small errors in the phase to neutral voltage measurements. This may give rise to an apparent residual voltage. This problem also extends to single phase power measurements that are also dependent upon their respective single phase voltages.

The phase to neutral voltage measurement accuracy can be improved by connecting 3, well matched, load resistors between the phase voltage inputs (C19, C20, C21) and neutral C22 thus creating a '**virtual**' neutral point. The load resistor values must be chosen so that their power consumption is within the limits of the VT. It is recommended that 10kΩ ±1% (6W) resistors are used for the 110V (Vn) rated relay, assuming the VT can supply this burden.

3.3.2 VT Single Point Earthing

The MiCOM P443/P446 will function correctly with conventional 3 phase VT's earthed at any one point on the VT secondary circuit. Typical earthing examples being neutral earthing, or B-phase (UK: "**yellow phase**" earthing).

3.4 Trip Circuit Supervision (TCS)

The trip circuit, in most protective schemes, extends beyond the relay enclosure and passes through components such as fuses, links, relay contacts, auxiliary switches and other terminal boards. This complex arrangement, coupled with the importance of the trip circuit, has led to dedicated schemes for its supervision.

Several trip circuit supervision scheme variants are offered. Although there are no dedicated settings for TCS, in the MiCOM P443/P446 the following schemes can be produced using the Programmable Scheme Logic (PSL). A user alarm is used in the PSL to issue an alarm message on the relay front display. If necessary, the user alarm can be re-named using the menu text editor to indicate that there is a fault with the trip circuit.

3.4.1 TCS Scheme 1

3.4.1.1 Scheme Description

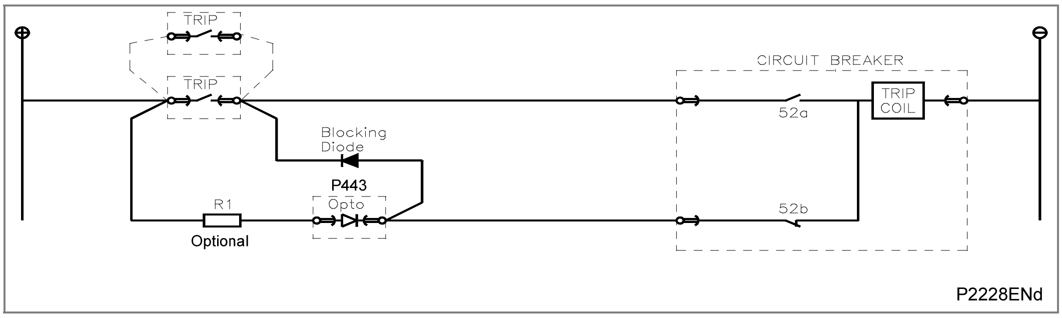


Figure 16 - TCS scheme 1

This scheme provides supervision of the trip coil with the breaker open or closed, however, pre-closing supervision is not provided. This scheme is also incompatible with latched trip contacts, as a latched contact will short out the opto for greater than the recommended DDO timer setting of 400ms. If breaker status monitoring is required a further 1 or 2 opto inputs must be used.

Note *A 52a CB auxiliary contact follows the CB position and a 52b contact is in the opposite state.*

When the breaker is closed, supervision current passes through the opto input, blocking diode and trip coil. When the breaker is open current still flows through the opto input and into the trip coil via the 52b auxiliary contact. Hence, no supervision of the trip path is provided whilst the breaker is open. Any fault in the trip path will only be detected on CB closing, after a 400ms delay.

Resistor R1 is an optional resistor that can be fitted to prevent mal-operation of the circuit breaker if the opto input is inadvertently shorted, by limiting the current to <60mA. The resistor should not be fitted for auxiliary voltage ranges of 30/34 volts or less, as satisfactory operation can no longer be guaranteed. Figure 13 shows the appropriate resistor value and voltage setting (OPTO CONFIG menu) for this scheme.

This TCS scheme will function correctly even without resistor R1, since the opto input automatically limits the supervision current to less that 10mA. However, if the opto is accidentally shorted the circuit breaker may trip.

Auxiliary Voltage (Vx)	Resistor R1 (ohms)	Opto Voltage Setting with R1 Fitted
48/54	1.2k	24/27
110/250	2.5k	48/54

Auxiliary Voltage (Vx)	Resistor R1 (ohms)	Opto Voltage Setting with R1 Fitted
220/250	5.0k	110/125
Note	*When R1 is not fitted the opto voltage setting must be set equal to supply voltage of the supervision circuit.*	

Table 13 - Resistor values and voltage settings required

3.4.1.2 Scheme 1 PSL

Figure 16 shows the scheme logic diagram for the TCS scheme 1. Any of the available opto inputs can be used to indicate whether or not the trip circuit is healthy. The delay on drop off timer operates as soon as the opto is energized, but will take 400ms to drop off / reset in the event of a trip circuit failure. The 400ms delay prevents a false alarm due to voltage dips caused by faults in other circuits or during normal tripping operation when the opto input is shorted by a self-reset trip contact. When the timer is operated the NC (normally closed) output relay opens and the LED and user alarms are reset.

The 50ms delay on pick-up timer prevents false LED and user alarm indications during the relay power up time, following an auxiliary supply interruption.

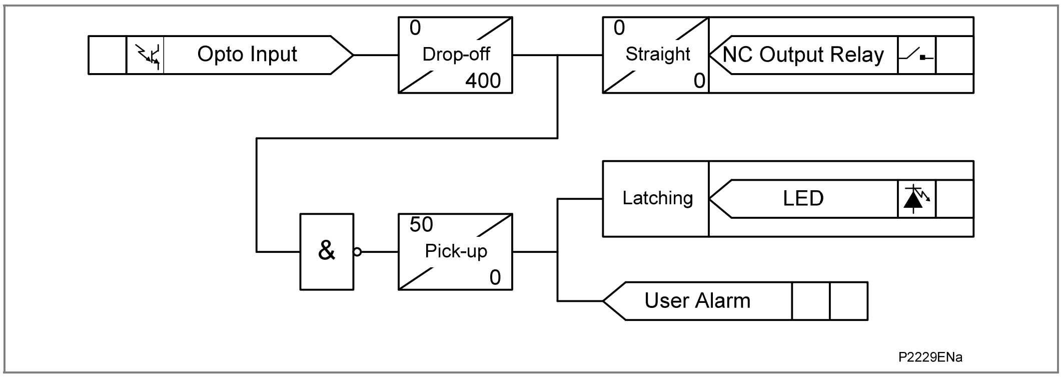

Opto Input
0
Drop-off
400
0
Straight
0
NC Output Relay
Latching
LED
&
50
Pick-up
0
User Alarm
P2229ENa

Figure 17 - PSL for TCS schemes 1 and 3

3.4.2 TCS Scheme 2

3.4.2.1 Scheme Description

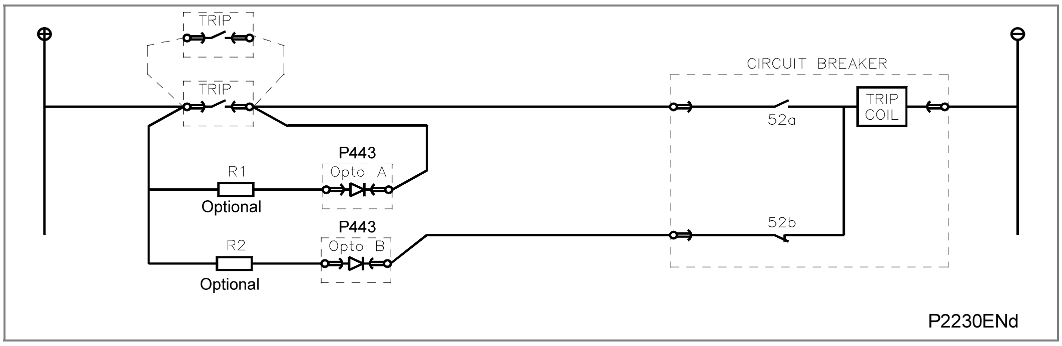

TRIP
TRIP
CIRCUIT BREAKER
52a
TRIP COIL
P443
R1
Opto A
Optional
P443
R2
Opto B
Optional
52b
P2230ENd

Figure 18 - TCS scheme 2

Much like scheme 1, this scheme provides supervision of the trip coil with the breaker open or closed and also does not provide pre-closing supervision. However, using two opto inputs allows the relay to correctly monitor the circuit breaker status since they are connected in series with the CB auxiliary contacts. This is achieved by assigning Opto A to the 52a contact and Opto B to the 52b contact. Provided the "**Circuit Breaker Status**" is set to "**52a and 52b**" (CB CONTROL column) the relay will correctly monitor the status of the breaker. This scheme is also fully compatible with latched contacts as the supervision current will be maintained through the 52b contact when the trip contact is closed.

When the breaker is closed, supervision current passes through opto input A and the trip coil. When the breaker is open current flows through opto input B and the trip coil. As with scheme 1, no supervision of the trip path is provided whilst the breaker is open. Any fault in the trip path will only be detected on CB closing, after a 400ms delay.

As with scheme 1, optional resistors R1 and R2 can be added to prevent tripping of the CB if either opto is shorted. The resistor values of R1 and R2 are equal and can be set the same as R1 in scheme 1.

3.4.2.2 Scheme 2 PSL

The PSL for this scheme (Figure 19) is practically the same as that of scheme 1. The main difference being that both opto inputs must be off before a trip circuit fail alarm is given.

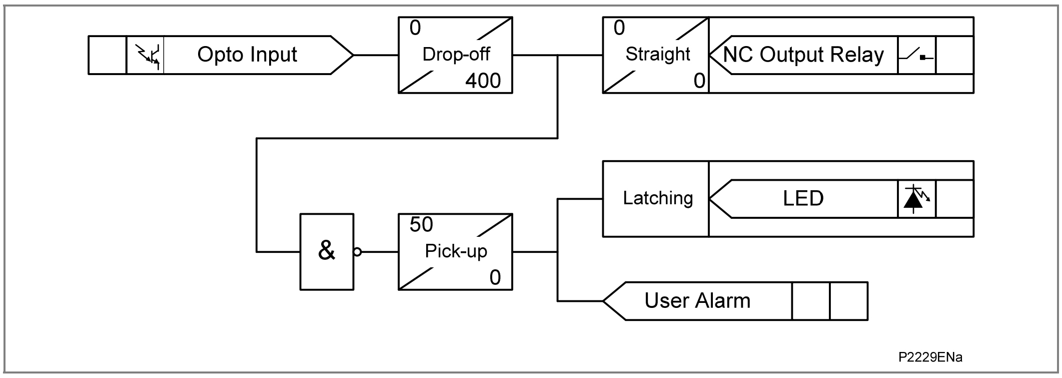


Figure 19 - PSL for TCS scheme 2

3.4.3 TCS Scheme 3

3.4.3.1 Scheme Description

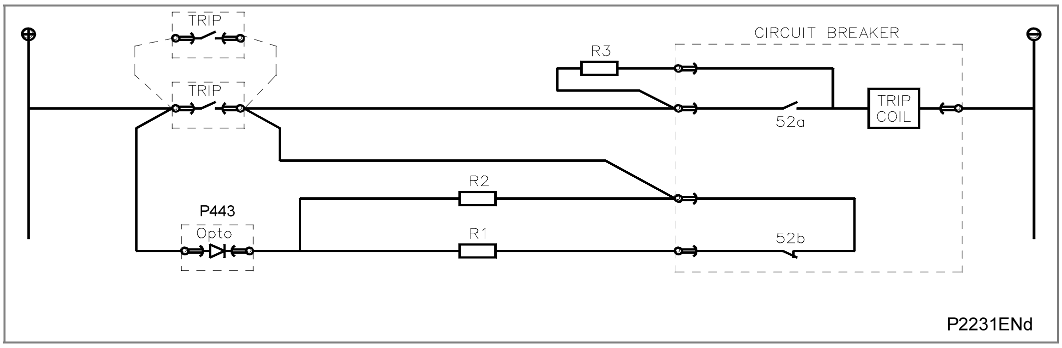


Figure 20 - TCS scheme 3

Scheme 3 is designed to provide supervision of the trip coil with the breaker open or closed, but unlike schemes 1 and 2, it also provides pre-closing supervision. Since only one opto input is used, this scheme is not compatible with latched trip contacts. If circuit breaker status monitoring is required a further 1 or 2 opto inputs must be used.

When the breaker is closed, supervision current passes through the opto input, resistor R2 and the trip coil. When the breaker is open current flows through the opto input, resistors R1 and R2 (in parallel), resistor R3 and the trip coil. Unlike schemes 1 and 2, supervision current is maintained through the trip path with the breaker in either state, thus giving full pre-closing supervision.

As with schemes 1 and 2, resistors R1 and R2 are used to prevent false tripping, if the opto-input is accidentally shorted. However, unlike the other two schemes, this scheme is dependent upon the position and value of these resistors. Removing them would result in incomplete trip circuit monitoring. The table below shows the resistor values and voltage settings required for satisfactory operation.

Auxiliary Voltage (Vx)	Resistor R1 & R2 (ohms)	Resistor R3 (ohms)	Opto Voltage Setting
48/54	1.2k	0.6k	24/27
110/250	2.5k	1.2k	48/54
220/250	5.0k	2.5k	110/125

Note *Scheme 3 is not compatible with auxiliary supply voltages of 30/34 volts and below.*

Table 14 - Resistor values and voltage settings required

3.4.3.2 Scheme 3 PSL

The PSL for scheme 3 is identical to that of scheme 1 (see Figure 16).

3.5 InterMiCOM^{64} Application Example

An example of how to apply the InterMiCOM^{64} scheme is given below. This example should be read in conjunction with the InterMiCOM^{64} section of the Operation (OP) section of this Technical Manual.

3.5.1 InterMiCOM^{64} Mapping for Three Ended Application - BLOCKING or PUR Example

Figure 21 shows a suggested InterMiCOM^{64} mapping:

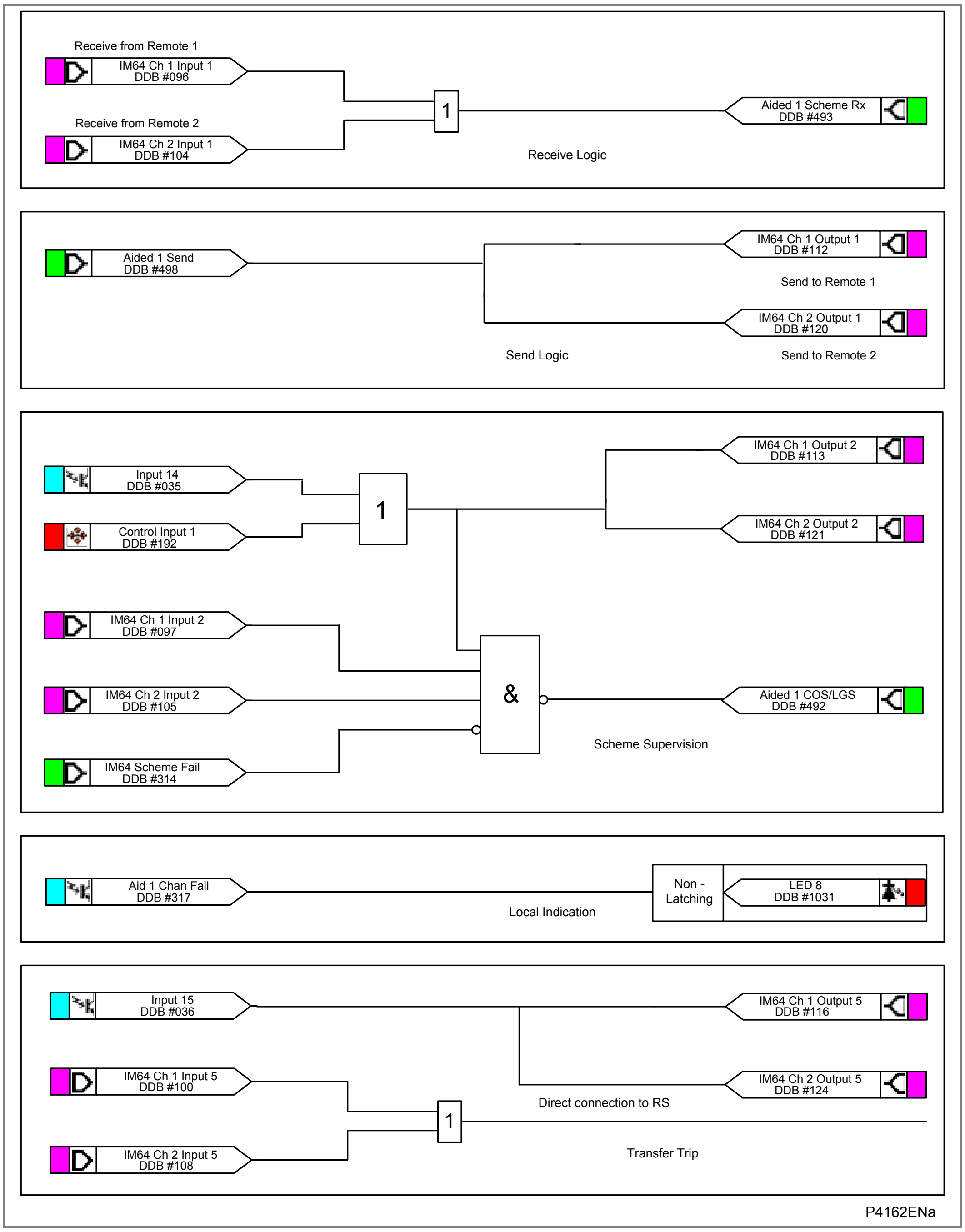

Receive from Remote 1
IM64 Ch 1 Input 1
DDB #096
Receive from Remote 2
IM64 Ch 2 Input 1
DDB #104
1
Aided 1 Scheme Rx
DDB #493
Receive Logic
Aided 1 Send
DDB #498
IM64 Ch 1 Output 1
DDB #112
Send to Remote 1
IM64 Ch 2 Output 1
DDB #120
Send Logic
Send to Remote 2
Input 14
DDB #035
Control Input 1
DDB #192
1
IM64 Ch 1 Output 2
DDB #113
IM64 Ch 2 Output 2
DDB #121
IM64 Ch 1 Input 2
DDB #097
IM64 Ch 2 Input 2
DDB #105
IM64 Scheme Fail
DDB #314
&
Aided 1 COS/LGS
DDB #492
Scheme Supervision
Aid 1 Chan Fail
DDB #317
Local Indication
Non - Latching
LED 8
DDB #1031
Input 15
DDB #036
IM64 Ch 1 Output 5
DDB #116
IM64 Ch 1 Input 5
DDB #100
IM64 Ch 2 Output 5
DDB #124
Direct connection to RS
1
IM64 Ch 2 Input 5
DDB #108
Transfer Trip
P4162ENa

Figure 21 - InterMiCOM^{64} mapping in a three ended application

3.5.2 InterMiCOM^{64} Application Example General Advice

MiCOM relays have standard, pre-configured aided scheme logic internal to each relay. Thus, it is not necessary to draw the zone logic for Permissive Underreach, Permissive Overreach or Blocking schemes within the PSL. To gain the benefit of selecting a proven and tested scheme, the standard "**Aided**" scheme logic should be used.

When InterMiCOM^{64} is being used as the transmission medium for the aided channel signal(s), all that is required is to create one-to-one mapping between the Aided scheme logic, and the InterMiCOM^{64} (IM64) signals to be used. The PSL editor is used to perform the simple mapping required.

In order to configure the signal SEND logic:

- Route the required Aided send DDB signal to the IM64 Output to be used

In order to configure the signal RECEIVE logic:

- Route the required IM64 Input signal to the Aided scheme Rx DDB input

3.5.3 Three-Ended Applications

The example in section 3.5.2 illustrates a three terminal application, in this case in a BLOCKING or PUR scheme mode.

> *Note:* *This breaks with the rule of the one-to-one mapping as described in section 3.5.2. In three terminal schemes, the input to the Aided scheme is some kind of logic combination of the signals received from the two remote ends:*

- BLOCKING schemes are recommended to take a logical OR of the incoming IM64 signals, before being mapped to Aided scheme Rx. This is to ensure that if the fault is declared as external at any line end, Zone 2 accelerated tripping at the local end is blocked.
- PERMISSIVE UNDERREACH schemes are recommended to take a logical OR of the incoming IM64 signals, before being mapped to Aided scheme Rx. Thus, if the fault is declared as internal at any remote line end, Zone 2 accelerated tripping at the local end is allowed. As Zone 1 is an underreaching element, it can only key the channel for an internal fault, so there is no need for AND logic.
- PERMISSIVE OVERREACH schemes are recommended to take a logical AND of the incoming IM64 signals, before being mapped to Aided scheme Rx. This is to ensure that the fault must be seen as forward from both remote ends before Zone 2 accelerated tripping at the local end is allowed. As Zone 2 keys the channel, confirmation of a forward decision at all three line ends must be confirmed before aided scheme tripping is permitted.

In all three terminal schemes, the send logic is a one-to-many mapping. The Aided send is mapped to the IM64 signals which transmit to both remote ends. The connection to Ch1 (channel 1), and Ch2 (channel 2) ensures communication to the two remote ends. In case of channel failure between any two relays, the '**Aided 1 COS/LGS**' signal will become high in the relay that is not receiving and activate the FallBackMode. Therefore, to preserve the stability in 3-ended blocking scheme, the corresponding '**IM_X DefaultValue**' in the setting file must be set high. It should be noted that in the PUR and POR schemes such a precaution is not necessary since the aided signal can not be sent via broken communications.

3.5.4 InterMiCOM^{64} Application Example Scheme Description

The scheme in Figure 21 is assumed as a case study. The top half of the page shows the mapping of the send and receive logic as already described. It can be seen that the first InterMiCOM bit (Input 1) is being used for the purposes of Aided scheme 1.

Notes	*Two Aided schemes are available, Aided 1 and Aided 2. This allows for example an independent Distance aided scheme, and a DEF aided scheme to be configured. Whether Aided 1 is used alone, or Aided 2 is used too will depend on the utility preference. Further detail is available in the* MiCOM *Technical Manual.* *The InterMiCOM64 bits are duplex in nature, in other words InterMiCOM64 bit 1 between the relay at line end A and B is completely independent from the same bit traveling from end B to A.* *For simplicity, it is recommended that Aided scheme 1 is mapped to IM64 bit 1.* *Likewise, where Aided scheme 2 is applied, it is more logical to assign IM64 bit 2, providing that it is not already used in the PSL for some other function.*

3.5.5 InterMiCOM^{64} Application Example Channel Supervision

For teleprotection schemes, it is commonplace to configure alarming in the event of channel failure. The third dotted box on the case study provides full monitoring of the scheme in three ended applications. Here, IM64 bit 2 is permanently energized when the channel is healthy. The OR gate shows how an opto input (L4) and a Control Input might be used as prerequisites for healthy signaling:

- The use of an opto input allows a check that correct DC battery voltages are present for local teleprotection purposes, or perhaps that a selector switch has not taken the scheme out of service.
- The use of a Control Input allows switching in or out of the teleprotection via menu commands on the relay concerned. This provides convenient in-out switching of the entire teleprotection scheme by visiting/addressing just one line end relay.

The exact logic condition to declare the local "**signaling healthy**" condition will be chosen such as to reflect the utility's practices. In the example shown, this logical condition is then mapped to IM64 Output 2 (bit 2), for transmitting to the two remote line ends.

In order to declare that the signaling scheme is healthy, bit 2 (the assigned health-check bit) must be received from both remote ends. This can be combined with a general check on InterMiCOM^{64} messaging, DDB#314. The AND gate shows that signaling is only healthy if:

- The local DC battery voltage/control state is set to allow teleprotection operation,
- The remote end health-check bits are both received successfully,
- The scheme alarms have not detected messaging failures (IM64 Scheme Fail).

A logical "**AND**" combination is used, with the gate output inverted to feed into the aided scheme logic. This scheme failure output then feeds the standard "**Channel out of Service**" (COS) logic.

The fourth dotted box illustrates how the same scheme failure alarm (COS) can then be simply mapped to any LED indication, or output contact for alarming.

Note	*If a simpler scheme is preferred, it is not necessary to assign a health-check bit. In such instances, the IM64 Scheme Fail alarm alone can be used to drive COS. However, if a test mode selection were to disable the aided scheme at one end, the other line ends would have no indication of the depleted operation.* *For this reason, the use of the health-check bit is recommended.*

3.5.6 InterMiCOM^{64} Application Example Transfer Trip

The case study scheme shows a suggested Transfer Trip ("**Intertrip**") in the lower dotted box area. This is an optional addition (or alternative) with any aided scheme. The example shows an opto input (L5) which is being used to initiate the intertrip, mapped to send IM64 bit 5 to both remote ends. On receipt of the intertrip bit from any remote line end, the OR gate is used to map the received intertrip to whichever output relay trips the local breaker. In the diagram, relay 3 is shown as an example.

Again it can be seen that the PSL is the means by which the InterMiCOM^{64} signals are driven, and to where any received bits are routed too.

3.5.7 InterMiCOM^{64} Application Example - Mapping for Two Ended Application

The same scheme principle as shown in Figure 21 applies in a two-ended application. The scheme will be simplified, whereby Aided Send signals are mapped directly to IM64 bits, on a one-to-one mapping. The IM64 bit received from the remote end is also mapped directly to the Aided Scheme Rx signal, requiring no AND or OR logic combination.

3.5.8 InterMiCOM^{64} Application Example - Dual Redundant Communications Channels

In dual redundant operation, the user has the option to send end-end signals via two paths. The two paths (channels) are defined as Ch1 and Ch2. Several factors can be taken into account when using this mode:

- The assignment of IM64 bits is completely independent, per channel. For example if all 8 possible bits per channel are assigned to discrete functions, this allows a total of 16 end-end signals.
- The receive logic should employ AND ("**both**") or OR ("**any"**) logic gate functions to combine the dual redundant signals, as appropriate to the desired operation.

3.5.9 InterMiCOM^{64} Application Example - Scheme Co-Ordination Timers

Distance and DEF and delta directional aided schemes use scheme co-ordination timers to ensure correct operation. The function of these is documented in the OP sections of the Technical Manual. However, when using InterMiCOM^{64} as the teleprotection channel, the time delays applied can be different to those used for traditional channels. This is due, mainly, to the fact that the response time of opto inputs and output contacts is bypassed. An output contact will take typically 3 to 5ms to close, and an opto input will take 1 to 2ms to recognize a change of state. Thus, using InterMiCOM^{64} will save around 5-6ms for I/O response time.

The new time delays appropriate for Dist Dly and Current Reversal Guard timers are as listed in the following sections. Where direct fiber connections are used for InterMiCOM^{64}, ignore the + *MUX* addition. Where a multiplexed link is used, the + *MUX* figure should account for the multiplexer response time. If this is unknown, it can be obtained for the specific installation using the appropriate measurement in the MEASUREMENTS 4 menu column.

3.5.9.1 InterMiCOM^{64} Application Example - Distance PUR Permissive Underreach

- Dist dly = zero

3.5.9.2 InterMiCOM^{64} Application Example - Distance POR Permissive Overreach

- Dist dly = zero
- tREV. Guard = 40ms + MUX

3.5.9.3 InterMiCOM^{64} Application Example - Distance Blocking

- Dist dly (50Hz) = 25ms + MUX
- Dist dly (60Hz) = 22ms + MUX
- tREV. Guard = 25ms + MUX

3.5.9.4 InterMiCOM^{64} Application Example - Directional Earth Fault (DEF) POR Permissive Overreach

- DEF dly = zero
- tREV. Guard = 50ms + MUX

3.5.9.5 InterMiCOM^{64} Application Example - Directional Earth Fault (DEF) Blocking

- DEF dly = 25ms + MUX
- tREV. Guard = 35ms + MUX

3.5.9.6 InterMiCOM^{64} Application Example - Delta Directional POR Permissive Overreach

- Delta dly = zero
- tREVERSAL GUARD = 40ms + MUX

3.5.9.7 InterMiCOM^{64} Application Example - Delta Directional Blocking

- Delta dly = 14ms + MUX
- tREVERSAL GUARD = 25ms + MUX

Note *When adding any multiplexer delays, the maximum response time of the multiplexed link should be assumed. This should include any addition for rerouting in self-healing networks.*

3.5.10 Fallback Mode for InterMiCOM^{64} bits

On temporary loss of the InterMiCOM^{64} channel, the user may select to latch the last healthy signal for a period of time, or to fallback to a chosen default value.

- For Intertripping schemes, reverting to a default state of 0 is recommended;
- For Blocking schemes set, reverting to a default state of 1 is recommended;
- For Permissive applications, latching the last healthy received state is recommended.

4 APPLICATION OF NON PROTECTION FUNCTIONS

4.1 Single and Three Phase Auto-Reclosing

4.1.1 Time Delayed and High Speed Auto-Reclosing

An analysis of faults on any overhead line network has shown that 80-90% are transient in nature.

In the majority of fault incidents, if the faulty line is immediately tripped out, and time is allowed for the fault arc to de-ionize, reclosure of the circuit breakers will result in the line being successfully re-energized. Auto-reclose schemes are employed to automatically re-close a switching device a set time after it has been opened due to operation of protection, where transient and semi-permanent faults are prevalent.

The principal benefit gained by the application of auto-reclosing to overhead line feeders is improved supply continuity and possibly reduced costs since fewer personnel may be required. On some systems the application of high speed auto-reclose may permit a higher level of power transfer while retaining transient stability for most faults which are likely to occur. High speed single phase auto-reclosure can offer increased benefits over high speed three phase auto-reclosure in terms of a higher power transfer limit and reduced stress on re-closing.

4.1.2 Auto-Reclose Logic Operating Sequence

The MiCOM P443 has a standard auto-reclose scheme configured to permit control of one circuit breaker only.

The MiCOM P446 can be used in applications such as breaker-and-a-half, or ring bus topologies, where two circuit breakers feed each line and both need to be controlled by the auto-reclose logic.

For high speed auto-reclose, only the instantaneous protection would normally be set to initiate auto-reclose. This is because for best results when applying high speed auto-reclose to improve a system stability limit, it is important that the fault should be cleared as quickly as possible from both line ends.

The auto-reclose scheme in the P446 provides auto-reclosing of a feeder terminal switched by two circuit breakers. The two circuit breakers are normally arranged to re-close sequentially with one designated leader circuit breaker re-closing after a set dead time followed, if the leader circuit breaker remains closed, by the second circuit breaker after a further delay, the follower time.

4.1.3 Auto-Reclose Setting Guidelines

4.1.3.1 Circuit Breaker Healthy

The P443/446 monitors the state of the auxiliary contacts (52A, 52B) of the controlled circuit breaker(s) to determine healthy circuit breaker status before allowing auto-reclose. Monitoring of the auxiliary contacts is recommended, but this check can be disabled by not allocating opto inputs to this function, and deliberately applying logic “**1**” onto the corresponding DDB signals within the PSL.

4.1.3.2 Number of Shots

An important consideration is the ability of the circuit breaker to perform several trip close operations in quick succession and the effect of these operations on the maintenance period.

The fact that 80 - 90% of faults are transient highlights the advantage of single shot schemes. If statistical information for the power system shows that a moderate percentage of faults are semi-permanent, further DAR shots may be used provided that system stability is not threatened.

Note DAR shots will always be three pole.

4.1.3.3 Dead Timer Setting

High speed auto-reclose may be required to maintain stability on a network with two or more power sources. For high speed auto-reclose the system disturbance time should be minimized by using fast protection, <30 ms, such as distance protection and fast circuit breakers <60 ms. For stability between two sources a system dead time of ≤300 ms may typically be required. The minimum system dead time considering just the CB is the trip mechanism reset time plus the CB closing time.

Minimum relay dead time settings are governed primarily by two factors:

- Time taken for de-ionization of the fault path
- Circuit breaker characteristics

Also it is essential that the protection fully resets during the dead time, so that correct time discrimination will be maintained after re-closure onto a fault. For high speed auto-reclose instantaneous reset of protection is required.

For highly interconnected systems synchronism is unlikely to be lost by the tripping out of a single line. Here the best policy may be to adopt longer dead times, to allow time for power swings on the system resulting from the fault to settle.

4.1.3.4 Follower Time Setting (P446 only)

In the application of auto-reclosing to a feeder terminal switched by two circuit breakers, the P446 provides the necessary control for both circuit breakers. The two circuit breakers are normally arranged to re-close sequentially with one designated leader circuit breaker reclosing after a set dead time followed, if the leader circuit breaker remains closed, by the second, follower, circuit breaker after a further delay, the follower time.

The follower time is provided to prevent un-necessary operation of the follower circuit breaker. The follower time should be set sufficiently long as to avoid an un-necessary closure of the follower circuit breaker where conditions are such that it would be required to trip again.

After expiry of the dead time, the leader circuit breaker will attempt a re-closure. The minimum value of the follower time should allow sufficient time for the auto-reclosure of the lead circuit breaker to be considered successful. Considering a worst case where re-closure is onto a dead line with a persistent fault at the remote end of the line, the fault will be detected by the zone 2 element of the local relay. In addition to the delays associated with the zone 2 scheme (P446 default zone 2 delay setting is 200ms, but will vary according to application), time must be allowed for the leader circuit breaker to re-trip (50 - 100ms), and a safety margin needs to be added so that typically, the minimum follower time could be around 500ms.

If the re-closure of the lead circuit breaker is successful, the follower circuit breaker can be allowed to re-close. Delaying the re-closure of the follower circuit breaker will allow any transients to decay before the switching and if the transient decay figure is known, can be used to determine a minimum follower time value. The larger of the two values can then be used as the minimum follower time.

Note	*Since the follower circuit breaker should only be re-closed if the system is healthy, and, since in a dual circuit breaker scheme where the system is healthy the follower circuit breaker acts more like a bus coupler, there is no real requirement for fast switching and a time delay in excess of 1s might be appropriate. Indeed, in the P446 default follower time is chosen as 5s and this can comfortably be applied to most applications.*

4.1.3.5 De-ionizing Time

The de-ionization time of a fault arc depends on circuit voltage, conductor spacing, fault current and duration, wind speed and capacitive coupling from adjacent conductors. As circuit voltage is generally the most significant, minimum de-ionizing times can be specified as in Table 30.

Note	*For single pole high-speed auto-reclose, the capacitive current induced from the healthy phases can increase the time taken to de-ionize fault arcs.*

Line Voltage (kV)	Minimum De-energization Time (s)
66	0.1
110	0.15
132	0.17
220	0.28
275	0.3
400	0.5

Table 15 - Minimum Fault Arc De-ionizing Time (Three Pole Tripping)

4.1.3.6 Example Minimum Dead Time Calculation

The following circuit breaker and system characteristics are to be used:

CB Operating time (Trip coil energized → Arc interruption): 50ms (a);

CB Opening + Reset time (Trip coil energized → Trip mechanism reset): 200ms (b);

Protection reset time: < 80ms (c);

CB Closing time (Close command → Contacts make): 85ms (d).

De-ionizing time for 220kV line:

280ms (e) for a three phase trip. (560ms for a single pole trip).

The minimum relay dead time setting is the greater of:

(a) + (c) = 50 + 80 = 130ms, to allow protection reset;

(a) + (e) - (d) = 50 + 280 - 85 = 245ms, to allow de-ionizing (three pole);

= 50 + 560 - 85 = 525ms, to allow de-ionizing (single pole).

In practice a few additional cycles would be added to allow for tolerances, so Dead Time 1 could be chosen as ≥ 300ms, and 1Pole Dead Time could be chosen as ≥ 600ms. The overall system dead time is found by adding (d) to the chosen settings, and then subtracting (a). (This gives 335ms and 635ms respectively here).

4.1.3.7 Reclaim Timer Setting

A number of factors influence the choice of the reclaim timer, such as;

- Fault incidence/Past experience - Small reclaim times may be required where there is a high incidence of recurrent lightning strikes to prevent unnecessary lockout for transient faults
- Spring charging time - For high speed auto-reclose the reclaim time may be set longer than the spring charging time. A minimum reclaim time of >5s may be needed to allow the CB time to recover after a trip and close before it can perform another trip-close-trip cycle. This time will depend on the duty (rating) of the CB. For delayed auto-reclose there is no need as the dead time can be extended by an extra CB healthy check AR Inhibit Time window time if there is insufficient energy in the CB
- Switchgear Maintenance - Excessive operation resulting from short reclaim times can mean shorter maintenance intervals
- The Reclaim Time setting is generally set greater than the tZ2 distance zone delay

4.2 Current Transformer Supervision

The residual voltage setting, "**CTS Vn< Inhibit**" and the residual current setting, "**CTS In> set**", should be set to avoid unwanted operation during healthy system conditions. For example "**CTS Vn< Inhibit**" should be set to at least 120% of the maximum steady state residual voltage. The "**CTS In> set**" will typically be set below minimum load current. The time-delayed alarm, "**CTS Time Delay**", is generally set to 5 seconds.

Where the magnitude of residual voltage during a ground/earth fault is unpredictable, the element can be disabled to prevent protection elements being blocked during fault conditions.

4.3 Circuit Breaker Condition Monitoring

4.3.1 Setting the Σ I^ Thresholds

Where overhead lines are prone to frequent faults and are protected by Oil Circuit Breakers (OCBs), oil changes account for a large proportion of the life cycle cost of the switchgear. Generally, oil changes are performed at a fixed interval of circuit breaker fault operations. However, this may result in premature maintenance where fault currents tend to be low, and hence oil degradation is slower than expected. The Σ I^ counter monitors the cumulative severity of the duty placed on the interrupter allowing a more accurate assessment of the circuit breaker condition to be made.

For OCBs, the dielectric withstand of the oil generally decreases as a function of ΣI^2t. This is where 'I' is the fault current broken, and '**t**' is the arcing time within the interrupter tank (not the interrupting time). As the arcing time cannot be determined accurately, the relay would normally be set to monitor the sum of the broken current squared, by setting '**Broken I^**' = 2.

For other types of circuit breaker, especially those operating on higher voltage systems, practical evidence suggests that the value of '**Broken I^**' = 2 may be inappropriate. In such applications '**Broken I^**' may be set lower, typically 1.4 or 1.5. An alarm in this instance may be indicative of the need for gas/vacuum interrupter HV pressure testing, for example. The setting range for '**Broken I^**' is variable between 1.0 and 2.0 in 0.1 steps. It is imperative that any maintenance program must be fully compliant with the switchgear manufacturer's instructions.

4.3.2 Setting the Number of Operations Thresholds

Every operation of a circuit breaker results in some degree of wear for its components. Thus, routine maintenance, such as oiling of mechanisms, may be based upon the number of operations. Suitable setting of the maintenance threshold will allow an alarm to be raised, indicating when preventative maintenance is due. Should maintenance not be carried out, the relay can be set to lockout the auto-reclose function on reaching a second operations threshold. This prevents further re-closure when the circuit breaker has not been maintained to the standard demanded by the switchgear manufacturer's maintenance instructions.

Certain circuit breakers, such as Oil Circuit Breakers (OCBs) can only perform a certain number of fault interruptions before requiring maintenance attention. This is because each fault interruption causes carbonizing of the oil, degrading its dielectric properties. The maintenance alarm threshold "**No CB Ops. Maint.**" may be set to indicate the requirement for oil sampling for dielectric testing, or for more comprehensive maintenance. Again, the lockout threshold "**No CB Ops. Lock**" may be set to disable auto-reclosure when repeated further fault interruptions could not be guaranteed. This minimizes the risk of oil fires or explosion.

4.3.3 Setting the Operating Time Thresholds

Slow CB operation is also indicative of the need for mechanism maintenance. Therefore, alarm and lockout thresholds (CB Time Maint./CB Time Lockout) are provided and are settable in the range of 5 to 500ms. This time is set in relation to the specified interrupting time of the circuit breaker.

4.3.4 Setting the Excessive Fault Frequency Thresholds

Persistent faults will generally cause auto-reclose lockout, with subsequent maintenance attention. Intermittent faults such as clashing vegetation may repeat outside of any reclaim time, and the common cause might never be investigated. For this reason it is possible to set a frequent operations counter on the relay which allows the number of operations "**Fault Freq. Count**" over a set time period "**Fault Freq. Time**" to be monitored. A separate alarm and lockout threshold can be set.

4.4 Read Only Mode

With IEC 61850 and Ethernet/Internet communication capabilities, security has become a pressing issue. The Px40 relay provides a facility to allow the user to enable or disable the change in configuration remotely.

Read only mode can be enabled/disabled for the following rear ports:

Rear Port 1	IEC 60870-5-103 and Courier protocols
Rear Port 2 (if fitted)	Courier protocol
Ethernet Port (if fitted)	Courier protocol (**tunnelled**)

5 TWO CB CONTROL (P446) WORKED EXAMPLE

A worked example of the control of a feeder switched by a dual circuit breaker is presented below. Detailed explanation of the control of such a scheme is presented in the operation section (P44y/EN OP) of this manual.

5.1 Introduction

This application example is for two shot, single and three phase, auto-reclosing at one end of a 500kV overhead transmission line switched by two circuit breakers in a “**one and a half switch**” configuration.

The single line diagram for the circuit is shown in Figure 22. This example outlines the settings required for auto-reclosing using a MiCOM P446 relay at sub-station A.

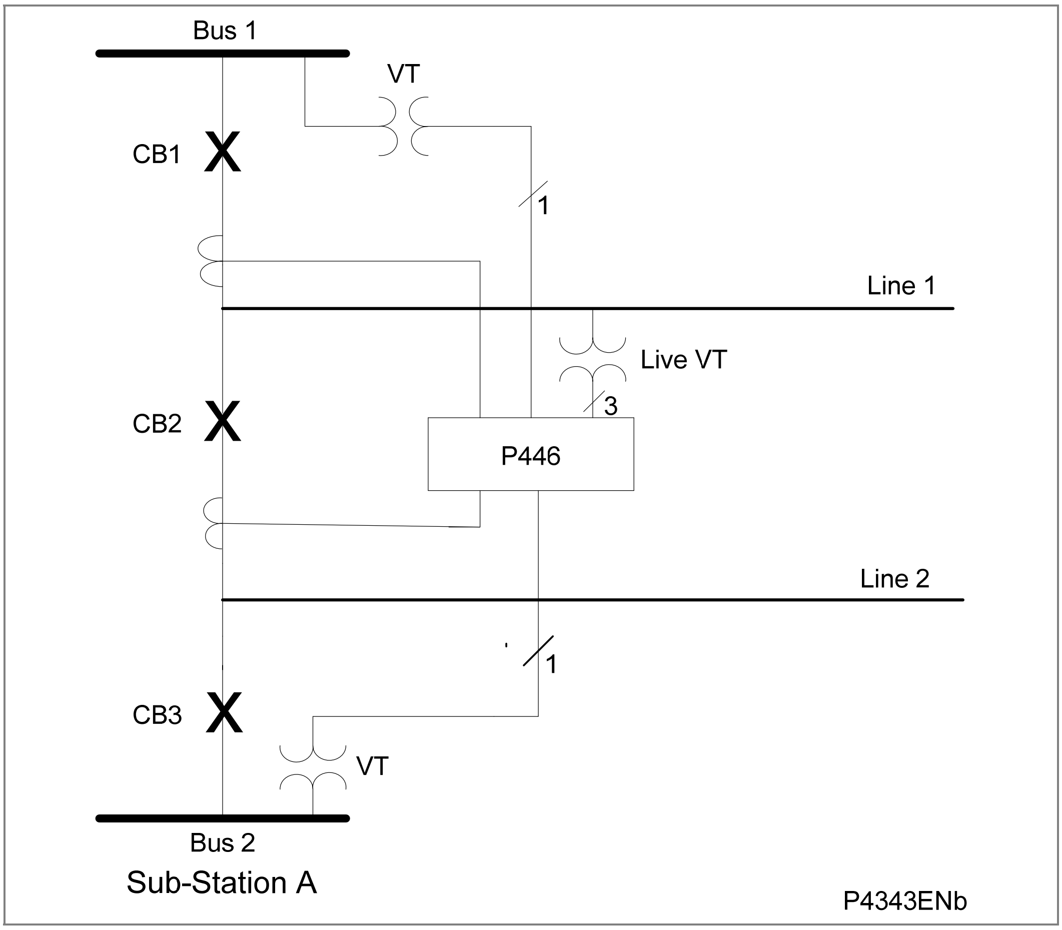


Figure 22 - Single line diagram - P446 dual circuit breaker control example

Auto-reclosing is considered to be initiated by distance protection tripping for a fault in Zone 1 or by aided high speed tripping. It is also possible to initiate auto-reclose by an external protection device, in which case the auto-reclose initiation would be provided by an opto input.

The circuit breakers are capable of either single phase or three phase tripping. Circuit breaker 1 (CB1) is designated as “**Leader**” and will re-close before Circuit breaker 2 (CB2). CB2 becomes the designated “**Follower**”, and will re-close after a “**Follower Time**” delay after CB1 has successfully re-closed.

The “**Leader**”, CB1 is arranged for single/three phase tripping and re-closing. The “**Follower**”, CB2 is arranged to trip three phase for all faults.

For a single phase fault, CB1 will trip single phase and CB2 will trip three phase. When the fault has been cleared, CB1 will re-close single phase without any system voltage checks after the selected “**Single Phase AR dead time**”, then, after the follower time delay, CB2 will re-close three phase, subject to a synchronism check between the line and Bus 2.

For a two phase or three phase fault, both circuit breakers will trip three phase. When the fault has been cleared, CB1 will re-close three phase after the selected “**Three Phase AR dead time**”, with either live bus/dead line or live bus/live line check synchronism between the line and Bus 1. When CB1 has successfully re-closed, after the follower time delay, CB2 will re-close three phase, subject to a synchronism check between the line and Bus 2.

For live line/live bus three phase re-closing of either circuit breaker, acceptable conditions are typically:

- The phase angle difference is not greater than 20 degrees;
- The slip frequency is not greater than 0.05Hz/s; and
- The magnitudes of both the applied line voltage and “**compensated**” Bus voltage are between 85% and 120% of nominal; and
- The magnitude of the difference between the applied line voltage and the “**compensated**” Bus voltage on either side of the circuit breaker is not greater than 10% of nominal.

It is assumed that re-closing at the remote line end will be either single phase with no system voltage checks, or three phase with live bus/live line synchronism check.

5.2 Circuit Breaker Status

The circuit breaker open/closed status is signaled to the auto-reclose scheme by separate type 52B auxiliary switch contacts on each circuit breaker pole (contact open when circuit breaker phase is closed, contact closed when the circuit breaker pole is open).

5.3 Voltage Inputs

The voltage inputs to the auto-reclose equipment are:

- 3 phase input (3P + N, magnitude 110V Ph-Ph, 63.5V Ph-N) from a line VT, connected to the Line VT (main VT) input;
- 1 phase input (A-B, magnitude 110V) from a Bus1 VT connected to the Bus1 VT (CB1 CS VT), input;
- 1 phase input (A-B, magnitude 110V) from a Bus2 VT connected to the Bus2 VT (CB2 CS VT), input.

Under healthy system conditions each bus VT (check sync VT) input leads the A-phase to Neutral Line VT input (main VT) by 30 degrees and has voltage magnitude of 110 V.

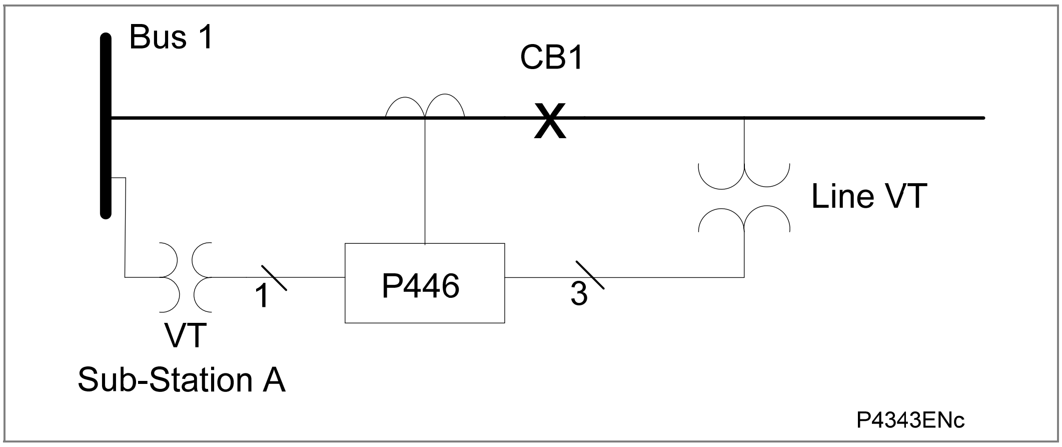


Figure 23 - VT connections

5.4 Application Settings

Typical values for the principal settings and user commands related to the auto-reclosing and system voltage check functions are given below. They are presented in the order in which they appear in the menu. The hexadecimal numbers in brackets/parentheses represent the Courier cell location in the menu.

5.4.1 CB CONTROL Menu

In the CB CONTROL column, the "**Autoreclose Mode**" command (07 0B) should be activated by setting to "**In Service**";

The data cell "**AR Status**" (07 0E) should display "**In Service**".

The "**CB1 Status Input**" (07 11): should be set to "**52B 1Pole**";

The "**CB2 Status Input**" (07 80): should be set to "**52B 1Pole**".

5.4.2 CONFIGURATION Menu

In the CONFIGURATION column, the following should all be set to "**Enabled**":

- "**Distance**" (09 0B)
- "System Checks" (09 23)
- "Auto-Reclose" (09 24)

5.4.3 CT & VT RATIOS Menu

In the CT & VT RATIOS column, the following should be set:

- "**Main VT Primary**" (0A 01): set nominal system primary ph-ph voltage (500kV);
- "**Main VT Sec'y**" (0A 02): set "**110 V**";
- "**CB1 CS VT Prim'y**" (0A 03): set nominal system primary ph-ph voltage (500kV);
- "CB1 CS VT Sec'y" (0A 04): set "110 V";
- "**CB2 CS VT Prim'y**" (0A 05): set nominal system primary ph-ph voltage (500kV);
- "CB2 CS VT Sec'y" (0A 06): set "110 V";
- "**CS Input**" (0A 0F): set "**A-N**";
- "**CB1 CS VT PhShft**" (0A 21): set "**-30 degrees**" (this creates a "**compensated**" Bus1 phase angle normally in phase with the selected "**CS Input**");
- "**CB1 CS VT Mag**" (0A 22): set "**0.58**" (this creates a "**compensated**" Bus1 voltage magnitude normally equal to that of the selected "**CS Input**");
- "**CB2 CS VT PhShft**" (0A 23): set "**-30 degrees**" (this creates a "**compensate**d" Bus2 phase angle normally in phase with the selected "**CS Input**");
- "**CB2 CS VT Mag**" (0A 24): set "**0.58**" (creates a "**compensated**" Bus2 voltage magnitude normally equal to that of the selected "**CS Input**");

(Note: VT secondary voltage settings in this section of the menu are always set in terms of phase to phase values, even when the actual inputs are taken from phase to neutral VT terminals).

5.4.4 GROUP 1 LINE PARAMETERS Menu

In the GROUP 1 LINE PARAMETERS column, the following should be set:

- “CB1Tripping Mode” (30 0C): set “1 and 3 Pole”;
- “CB2Tripping Mode” (30 0E): set “3 Pole”.

5.4.5 GROUP 1 DISTANCE Menu

- In the GROUP 1 DISTANCE column, appropriate settings should be applied and the elements enabled as per the operational requirements. Operation of the zone 1 tripping and/or the operation of the aided schemes will initiate auto-reclose.

5.4.6 GROUP 1 SYSTEM CHECKS Menu

In the GROUP 1 SYSTEM CHECKS column, the following should be set:

- “**Live Line**” (48 85): set “**32 V**” (typical setting 50% of nominal applied voltage of selected “**CS Input**” (set to A-N in this example));
- “**Dead Line**” (48 86): set “**13 V**” (typical setting 20% of nominal applied voltage of selected “**CS Input**” (set to A-N in this example));
- “**Live Bus 1**” (48 87): set “**32 V**” (typical setting 50% of “**compensated**” nominal applied voltage);
- “**Dead Bus 1**” (48 88): set “**13 V**” (typical setting 20% of “**compensated**” nominal applied voltage).
- “**Live Bus 2**” (48 89): set “**32 V**” (typical setting 50% of “**compensated**” nominal applied voltage);
- “**Dead Bus 2**” (48 8A): set “**13 V**” (typical setting 20% of “**compensated**” nominal applied voltage);
- “**CS UV**” (48 8B): set “**54 V**” (typical setting 85% of nominal applied voltage of selected “**CS Input**” (set to A-N in this example));
- “**CS OV**” (48 8C): set “**76 V**” (typical setting 120% of nominal applied voltage of selected “**CS Input**” (set to A-N in this example));
- “Sys Checks CB1” (48 8D): set “Enabled”;
- “CB1 CS Volt. Blk” (48 8E): set “V< V> and Vdiff”;
- “CB1 CS1 Status” (48 8F): set “Enabled”;
- “CB1 CS1 Angle” (48 90): set “20 degrees”;
- “**CB1 CS1 Vdiff**” (48 91): set “**6.5 V**” (typical setting 10% of nominal applied voltage of selected “**CS Input**” (set to A-N in this example));
- “CB1 CS1 SlipCtrl” (48 92): set “Enabled”;
- “CB1 CS1 SlipFreq” (48 93): set “0.05Hz”;
- “CB1 CS2 Status” (48 94): set “Disabled”;
- “Sys Checks CB2” (48 9B): set “Enabled”;
- “CB2 CS Volt. Blk” (48 9C): set “V< V> and Vdiff”;
- “CB2 CS1 Status” (48 9D): set “Enabled”;
- “CB2 CS1 Angle” (48 9E): set “20 degrees”;

- "**CB2 CS1 Vdiff**" (48 9F): set "**6.5 V**" (typical setting 10% of nominal applied voltage of selected "**CS Input**" (set to A-N in this example));
- "CB2 CS1 SlipCtrl" (48 A0): set "Enable";
- "CB2 CS1 SlipFreq" (48 A1): set "0.05Hz";
- "CB2 CS2 Status" (48 94): set "Disabled";

5.4.7 GROUP 1 AUTORECLOSE Menu:

In the GROUP 1 AUTORECLOSE column, the following should be set:

- "**Num CBs**" (49 50): set "**Both CB1&CB2**";
- "Lead/Foll ARMode" (49 53): set "L 1/3P, F 3P";
- "Leader Select By" (49 55): set "Menu";
- "Select Leader" (49 56): set "Sel Leader CB1";
- "BF if LFail Cls" (49 57): set "Enabled";
- "**AR Shots**" (49 59): set "**2**";
- "Multi Phase AR" (49 5C): set "Allow Autoclose";
- "**Discrim Time**" (49 5D): set "**0.5 sec**" (set as per application requirements);
- "**CB IS Time**" (49 60): set "**5 sec**" (this requires the circuit breaker to have been in the closed position for at least 5 seconds before fault occurrence will enable auto-reclose initiation. It is designed to prevent auto-reclosure for a fault immediately after manual circuit breaker closure (switch on to fault));
- "CB IS Memory Time" (49 61): set "0.5 sec";
- "**DT Start by Prot**" (49 62): set "**Protection Reset**" (measured dead time starts when protection resets);
- "3PDTStart WhenLD" (49 63): set "Disabled";
- "DTStart by CB Op" (49 64): set "Disabled";
- "**SP AR Dead Time**" (49 67): set "**0.5 sec**" (typical);
- "**3P AR DT Shot 1**" (49 68): set "**0.3 sec**" (or as per application requirements and considerations at circuit breaker location);
- "**3P AR DT Shot 2**" (49 68): set "**60 sec**" (or as per application requirements and considerations at the circuit breaker location);
- "**Follower Time**" (49 6C): set "**5 sec**" (typical);
- "**SPAR ReclaimTime**" (49 6D): set "**180 sec**" (or as required to suit circuit breaker duty cycle);
- "**3P AR ReclaimTime**" (49 6E): set "**180 sec**" (or as required to suit circuit breaker duty cycle);
- "AR CBHealthyTime" (49 6F): set "0.3 sec";
- "AR CheckSyncTime" (49 70): set "0.3 sec";
- "**Z1 AR**" (49 72): set "**Initiate AR**";
- "Dist Aided AR" (49 74): set "Initiate AR";
- All other protection inputs ("**Z2T AR**" (49 72) onwards): set "**Block AR**";
- "**CB1L SC all**" (49 A6): set "**Enabled**";

- “CB1L SC Shot 1” (49 A7): set “Enabled”;
- “CB1L SC ClsNoDly” (49 A8): set “Disabled”;
- “**CB1L SC CS1**” (49 A9): set “**Enabled**”;
- “**CB1L SC CS2**” (49 AA): set “**Disabled**”;
- “**CB1L SC DLLB**” (49 AB): set “**Enabled**”;
- “CB1L SC LLDB” (49 AC): set “Disabled”;
- “CB1L SC DLDB” (49 AD): set “Disabled”;
- “**CB2F SC all**” (49 BD): set “**Enabled**”;
- “CB2F SC Shot 1” (49 BE): set “Enabled”;
- “**CB2F SC CS1**” (49 BF): set “**Enabled**”;
- “**CB2F SC CS2**” (49 C0): set “**Disabled**”;
- “CB2F SC DLLB” (49 C1): set “Disabled”;
- “CB2F SC LLDB” (49 C2): set “Disabled”;
- “CB2F SC DLDB” (49 C3): set “Disabled”.

5.5 Programmable Scheme Logic (PSL) Mapping

The PSL mapping of some of the opto inputs and relay outputs for this application example are shown below for guidance.

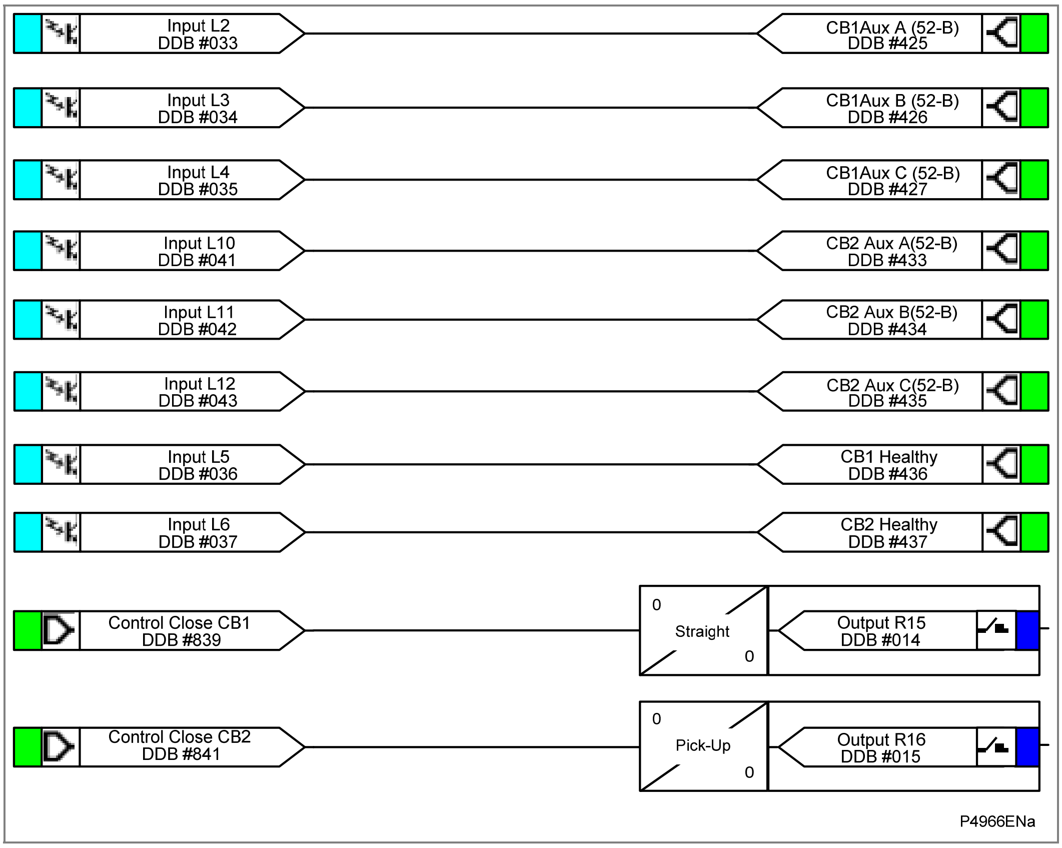

Input L2
DDB #033
CB1Aux A (52-B)
DDB #425
Input L3
DDB #034
CB1Aux B (52-B)
DDB #426
Input L4
DDB #035
CB1Aux C (52-B)
DDB #427
Input L10
DDB #041
CB2 Aux A(52-B)
DDB #433
Input L11
DDB #042
CB2 Aux B(52-B)
DDB #434
Input L12
DDB #043
CB2 Aux C(52-B)
DDB #435
Input L5
DDB #036
CB1 Healthy
DDB #436
Input L6
DDB #037
CB2 Healthy
DDB #437
Control Close CB1
DDB #839
0
Straight
0
Output R15
DDB #014
Control Close CB2
DDB #841
0
Pick-Up
0
Output R16
DDB #015
P4966ENa

Figure 24 - PSL mapping of some of the opto inputs and relay outputs

In order to test the application example, as well as applying appropriate current and voltage connections, the settings, and the PSL, it will be necessary to employ some secondary test equipment capable of mimicking the circuit breaker status.

For any specific application, the Application Engineer must analyze the particular power systems to determine the appropriate settings and PSL mappings.

6 CURRENT TRANSFORMER REQUIREMENTS

6.1 Zone 1 Reach Point Accuracy (RPA)

$Vk \geq K_{RPA} \times IF\ Z1 \times (1+ X/R).\ (RCT + RL)$

Where:

Vk = Required CT knee point voltage (volts)
K_{RPA} = Fixed dimensioning factor = **always 0.6**
IF_{Z1} = Max. secondary phase fault current at Zone 1 reach point (A)
X/R = Primary system reactance/resistance ratio
RCT = CT secondary winding resistance (Ω)
RL = Single lead resistance from CT to relay (Ω)

6.2 Zone 1 Close-Up Fault Operation

An additional calculation must be performed for all cables, and any lines where the source impedance ratio might be less than SIR = 2.

$Vk \geq Kmax \times IF\ max \times (RCT + RL)$

Where:

Kmax = Fixed dimensioning factor = **always 1.4**
IF max = Max. secondary phase fault current (A).

Then, the highest of the two calculated knee points must be used.

Note	*It is not necessary to repeat the calculation for earth faults, as the phase reach calculation (3φ) is the worst-case for CT dimensioning.*

6.3 Recommended CT Classes (British and IEC)

Class X current transformers with a knee point voltage greater or equal than that calculated can be used.

Class 5P protection CTs can be used, noting that the knee point voltage equivalent these offer can be approximated from:

$Vk = (VA \times ALF)/In + (RCT \times ALF \times In)$

Where:

VA = Voltampere burden rating
ALF = Accuracy limit factor
In = CT nominal secondary current

6.4 Determining Vk for an IEEE “C" class CT

Where American/IEEE standards are used to specify CTs, the C class voltage rating can be checked to determine the equivalent Vk (knee point voltage according to IEC). The equivalence formula is:

$Vk = [(C\text{ rating in volts}) \times 1.05] + [100 \times RCT]$

7 HIGH BREAK OUTPUT CONTACTS

The high break contacts allow the elimination of auxiliary relays. This in turn helps in the provision of cost effective solutions, minimizing space, wiring, commissioning time, etc.

According to the model selected, in addition to standard output relay boards, one or two '**high break**' output relay boards can be fitted. Each houses four normally open output contacts suitable for breaking loads higher than can be broken with the standard contacts. The performance and possible application scenarios of these contacts are described in the Technical Data (TD) and Firmware Design (FD) sections of this manual.

8 AUXILIARY SUPPLY FUSE RATING

In the Safety section of this manual, the maximum allowable fuse rating of 16 A is quoted. To allow time grading with fuses upstream, a lower fuselink current rating is often preferable. Use of standard ratings of between 6 A and 16 A is recommended. Low voltage fuselinks, rated at 250 V minimum and compliant with IEC60269-2 general application type gG are acceptable, with high rupturing capacity. This gives equivalent characteristics to HRC "**red spot**" fuses type NIT/TIA often specified historically.

The table below recommends advisory limits on relays connected per fused spur. This applies to MiCOM Px40 series devices with hardware suffix C and higher, as these have inrush current limitation on switch-on, to conserve the fuse-link.

Maximum Number of MiCOM Px40 Relays Recommended Per Fuse				
Battery Nominal Voltage	**6 A**	**10 A Fuse**	**15 or 16 A Fuse**	**Fuse Rating > 16 A**
24 to 54 V	2	4	6	Not permitted
60 to 125 V	4	8	12	Not permitted
138 to 250 V	6	10	16	Not permitted

Table 16 - Maximum Number of MiCOM Px40 Relays Recommended Per Fuse

Alternatively, Miniature Circuit Breakers (MCB) may be used to protect the auxiliary supply circuits.

Notes:

PROGRAMMABLE LOGIC

CHAPTER 7

Date:	02/2013
Hardware Suffix:	K
Software Version:	57
Connection Diagrams:	10P44303 (SH 01 and 03) 10P44304 (SH 01 and 03) 10P44305 (SH 01 and 03) 10P44306 (SH 01 and 03) 10P44600 10P44601 (SH 1 to 2) 10P44602 (SH 1 to 2) 10P44603 (SH 1 to 2)

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LEDs 95

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Opto Input Mappings 105
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LEDs 109

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Output Contacts 120
LEDs 133

MiCOM P446 with standard contacts PSL 16 STD + 8 High break relays 132
Opto Input Mappings 132
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Notes:

1 PROGRAMMABLE LOGIC

1.1 Overview

The purpose of the Programmable Scheme Logic (PSL) is to allow the relay user to configure an individual protection scheme to suit their own particular application. This is achieved through the use of programmable logic gates and delay timers.

The input to the PSL is any combination of the status of opto inputs. It is also used to assign the mapping of functions to the opto inputs and output contacts, the outputs of the protection elements, e.g. protection starts and trips, and the outputs of the fixed protection scheme logic. The fixed scheme logic provides the relay's standard protection schemes. The PSL itself consists of software logic gates and timers. The logic gates can be programmed to perform a range of different logic functions and can accept any number of inputs. The timers are used either to create a programmable delay, and/or to condition the logic outputs, e.g. to create a pulse of fixed duration on the output regardless of the length of the pulse on the input. The outputs of the PSL are the LEDs on the front panel of the relay and the output contacts at the rear.

The execution of the PSL logic is event driven; the logic is processed whenever any of its inputs change, for example as a result of a change in one of the digital input signals or a trip output from a protection element. Also, only the part of the PSL logic that is affected by the particular input change that has occurred is processed. This reduces the amount of processing time that is used by the PSL; even with large, complex PSL schemes the relay trip time will not lengthen.

This system provides flexibility for the user to create their own scheme logic design. However, it also means that the PSL can be configured into a very complex system, hence setting of the PSL is implemented through the PC support package MiCOM S1.

1.2 MiCOM S1 Px40 PSL editor

To access the Px40 PSL Editor menu click the icon. The PSL Editor module enables you to connect to any MiCOM device front port, retrieve and edit its Programmable Scheme Logic files and send the modified file back to a MiCOM Px40 device.

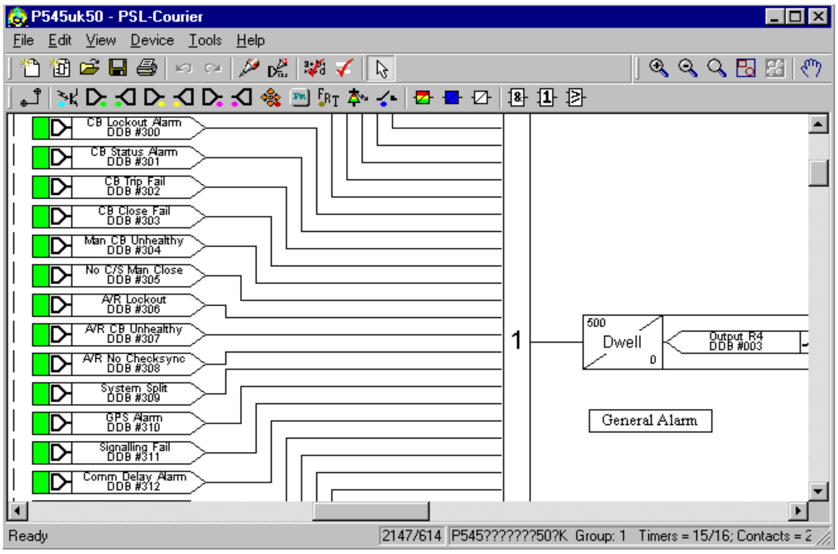

P545uk50 - PSL-Courier
File
Edit
View
Device
Tools
Help
CB Lockout Alarm DDB #300
CB Status Alarm DDB #301
CB Trip Fail DDB #302
CB Close Fail DDB #303
Man CB Unhealthy DDB #304
No C/S Man Close DDB #305
A/R Lockout DDB #306
A/R CB Unhealthy DDB #307
A/R No Checksync DDB #308
System Split DDB #309
GPS Alarm DDB #310
Signalling Fail DDB #311
Comm Delay Alarm DDB #312
1
500
Dwell
0
Output R4 DDB #003
General Alarm
Ready
2147/614
P545???????50?K Group: 1
Timers = 15/16; Contacts = 2

Figure 1 - PSL screenshot

1.3 How to use MiCOM Px40 PSL editor

With the MiCOM Px40 PSL Module you can:

- Start a new PSL diagram
- Extract a PSL file from a MiCOM Px40 IED
- Open a diagram from a PSL file
- Add logic components to a PSL file
- Move components in a PSL file
- Edit link of a PSL file
- Add link to a PSL file
- Highlight path in a PSL file
- Use a conditioner output to control logic
- Download PSL file to a MiCOM Px40 IED
- Print PSL files

For details of how to use these functions, please refer to MiCOM S1 Users Manual.

1.4 Warnings

Before the scheme is sent to the relay checks are done. Various warning messages may be displayed as a result of these checks.

The Editor first reads in the model number of the connected relay, and then compares it with the stored model number. A "wildcard" comparison is employed. If a model mismatch occurs then a warning will be generated before sending commences. Both the stored model number and that read-in from the relay are displayed along with the warning; the onus is on you to decide if the settings to be sent are compatible with the connected relay. Wrongly ignoring the warning could lead to undesired behavior in the relay.

If there are any potential problems of an obvious nature then a list will be generated. The types of potential problems that the program attempts to detect are:

- One or more gates, LED signals, contact signals, and/or timers have their outputs linked directly back to their inputs. An erroneous link of this sort could lock up the relay, or cause other more subtle problems to arise.
- Inputs to Trigger (ITT) exceeds the number of inputs. A programmable gate has its ITT value set to greater than the number of actual inputs; the gate can never activate.

Note *There is no lower ITT value check. A 0-value does not generate a warning.*

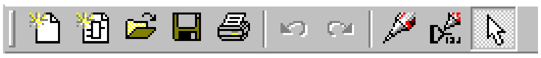
- Too many gates. There is a theoretical upper limit of 256 gates in a scheme, but the practical limit is determined by the complexity of the logic. In practice the scheme would have to be very complex, and this error is unlikely to occur.
- Too many links. There is no fixed upper limit to the number of links in a scheme. However, as with the maximum number of gates, the practical limit is determined by the complexity of the logic. In practice the scheme would have to be very complex, and this error is unlikely to occur.

1.5 Toolbar and Commands

There are a number of toolbars available for easy navigation and editing of PSL.

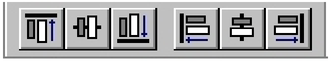
1.5.1 Standard Tools

For file management and printing.



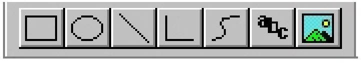
1.5.2 Alignment Tools

To snap logic elements into horizontally or vertically aligned groupings.



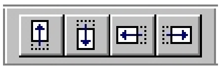
1.5.3 Drawing Tools

To add text comments and other annotations, for easier reading of PSL schemes.



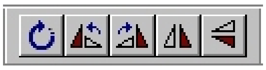
1.5.4 Nudge Tools

To move logic elements.



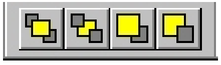
1.5.5 Rotation Tools

Tools to spin, mirror and flip.



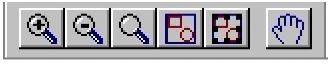
1.5.6 Structure Tools

To change the stacking order of logic components.

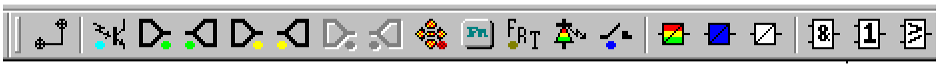


1.5.7 Zoom and Pan Tools

For scaling the displayed screen size, viewing the entire PSL, or zooming to a selection.



1.5.8 Logic Symbols



This toolbar provides icons to place each type of logic element into the scheme diagram. Not all elements are available in all devices. Icons will only be displayed for those elements available in the selected device.

Link

Create a link between two logic symbols.

Opto Signal

Create an opto signal.

Input Signal

Create an input signal.

Output Signal

Create an output signal.

GOOSE In

Create an input signal to logic to receive an IEC 61850 GOOSE message transmitted from another IED.

GOOSE Out

Create an output signal from logic to transmit an IEC 61850 GOOSE message to another IED.

Control In

Create an input signal to logic that can be operated from an external command.

InterMiCOM In

Create an input signal to logic to receive an InterMiCOM command transmitted from another IED.

InterMiCOM Out n

Create an output signal from logic to transmit an InterMiCOM command to another IED.

Function Key

Create a function key input signal.

Trigger Signal

Create a fault record trigger.

LED Signal

Create an LED input signal that repeats the status of tri-color LED.

Contact Signal

Create a contact signal.

LED Conditioner

Create an LED conditioner for tri-color LED.

Contact Conditioner

Create a contact conditioner.

Timer

Create a timer.

AND Gate

Create an AND Gate.

OR Gate

Create an OR Gate.

Programmable Gate

Create a programmable gate.

1.6 PSL Logic Signals Properties

The logic signal toolbar is used for the selection of logic signals.

Performing a right-mouse click on any logic signal will open a context sensitive menu and one of the options for certain logic elements is the **Properties** command. Selecting the Properties option will open a Component Properties window, the format of which will vary according to the logic signal selected.

Properties of each logic signal, including the Component Properties windows, are shown in the following sub-sections:

1.6.1 Signal Properties Menu

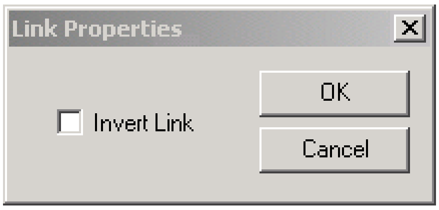
The **Signals List** tab is used for the selection of logic signals.

The signals listed will be appropriate to the type of logic symbol being added to the diagram. They will be of one of the following types:

1.6.2 Link Properties

Links form the logical link between the output of a signal, gate or condition and the input to any element.

Any link that is connected to the input of a gate can be inverted via its properties window. An inverted link is indicated with a “bubble” on the input to the gate. It is not possible to invert a link that is not connected to the input of a gate.



1.6.3 Rules for Linking Symbols

Links can only be started from the output of a signal, gate, or conditioner, and can only be ended on an input to any element.

Since signals can only be either an input or an output then the concept is somewhat different. In order to follow the convention adopted for gates and conditioners, input signals are connected from the left and output signals to the right. The Editor will automatically enforce this convention.

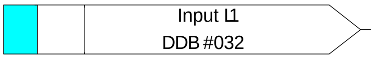
A link attempt will be refused where one or more rules would otherwise be broken. A link will be refused for the following reasons:

- An attempt to connect to a signal that is already driven. The cause of the refusal may not be obvious, since the signal symbol may appear elsewhere in the diagram. Use “Highlight a Path” to find the other signal.
- An attempt is made to repeat a link between two symbols. The cause of the refusal may not be obvious, since the existing link may be represented elsewhere in the diagram.

1.6.4 Opto Signal Properties

Each opto input can be selected and used for programming in PSL. Activation of the opto input will drive an associated DDB signal.

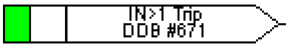
For example activating opto input L1 will assert DDB 032 in the PSL.



1.6.5 Input Signal Properties

Relay logic functions provide logic output signals that can be used for programming in PSL. Depending on the relay functionality, operation of an active relay function will drive an associated DDB signal in PSL.

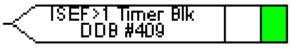
For example DDB 671 will be asserted in the PSL should the active earth fault 1, stage 1 protection operate/trip.



1.6.6 Output Signal Properties

Relay logic functions provide logic input signals that can be used for programming in PSL. Depending on the relay functionality, activation of the output signal will drive an associated DDB signal in PSL and cause an associated response to the relay function

For example, if DDB 409 is asserted in the PSL, it will block the sensitive earth function stage 1 timer.

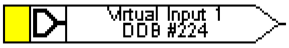


1.6.7 GOOSE Input Signal Properties

The Programmable Scheme Logic interfaces with the GOOSE Scheme Logic (see S1 users manual) by means of 32 Virtual inputs. The Virtual Inputs can be used in much the same way as the Opto Input signals.

The logic that drives each of the Virtual Inputs is contained within the relay’s GOOSE Scheme Logic file. It is possible to map any number of bit-pairs, from any subscribed device, using logic gates onto a Virtual Input (see S1 Users manual for more details).

For example DDB 224 will be asserted in PSL should virtual input 1 operate.

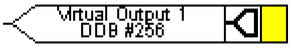


1.6.8 GOOSE Output Signal Properties

The Programmable Scheme Logic interfaces with the GOOSE Scheme Logic by means of 32 Virtual outputs.

It is possible to map virtual outputs to bit-pairs for transmitting to any subscribed devices (see S1 Users manual for more details).

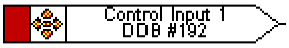
For example if DDB 256 is asserted in PSL, Virtual Output 32 and its associated mappings will operate.



1.6.9 Control In Signal Properties

There are 32 control inputs which can be activated vi e relay menu, ‘hotkeys’ or via rear communications. Depending on the programmed setting i.e. latched or pulsed, an associated DDB signal will be activated in PSL when a control input is operated.

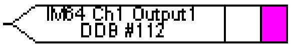
For example operate control input 1 to assert DDB 192 in the PSL.



1.6.10 InterMiCOM (and InterMiCOM^{64}) Commands Properties

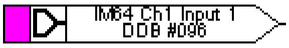
1.6.10.1 InterMiCOM Out

There are 16 InterMiCOM^{64} outputs that could be selected and use for teleprotection, remote commands, etc. “InterMiCOM Out” is a send command to a remote end that could be mapped to any logic output or opto input. This will be transmitted to the remote end as corresponding “InterMiCOM In” command.



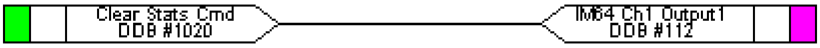
1.6.10.2 InterMiCOM In

There are 16 InterMiCOM^{64} inputs that could be selected and use for teleprotection, remote commands, etc. “InterMiCOM In” is a received signal from remote end that could be mapped to a selected output relay or logic input.

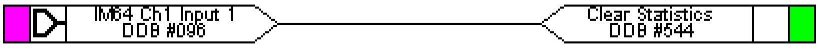


Example

Relay End A
At end A, InterMiCOM Output 1 is mapped to the command indication “Clear Statistics” (issued at end A)



Relay End B
At end B, InterMiCOM Input 1 is mapped to the command “Clear Statistics”

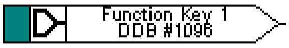


Upon receive of IM64 1 from relay at end A, the relay at end B will reset its statistics.

1.6.11 Function Key Properties

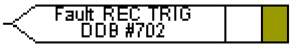
Each function key can be selected and used for programming in PSL. Activation of the function key will drive an associated DDB signal and the DDB signal will remain active depending on the programmed setting i.e. toggled or normal. Toggled mode means the DDB signal will remain latched or unlatched on key press and normal means the DDB will only be active for the duration of the key press.

For example operate function key 1 to assert DDB 1096 in the PSL.



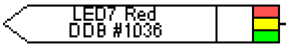
1.6.12 Fault Recorder Trigger Properties

The fault recording facility can be activated, by driving the fault recorder trigger DDB signal. For example assert DDB 702 to activate the fault recording in the PSL.


Fault REC TRIG
DDB #702

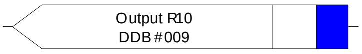
1.6.13 LED Signal Properties

All programmable LEDs will drive associated DDB signal when the LED is activated. For example DDB 1036 will be asserted when LED 7 is activated.


LED7 Red
DDB #1036

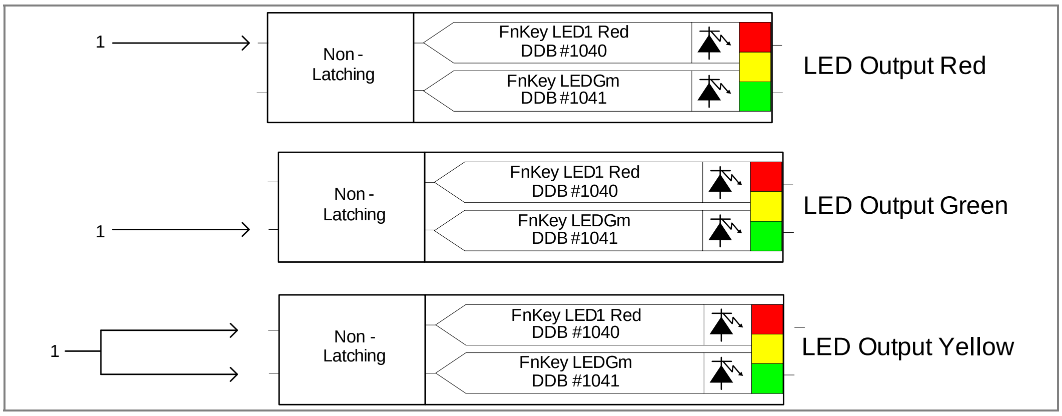
1.6.14 Contact Signal Properties

All relay output contacts will drive associated DDB signal when the output contact is activated. For example DDB 009 will be asserted when output R10 is activated.


Output R10
DDB #009

1.6.15 LED Conditioner Properties

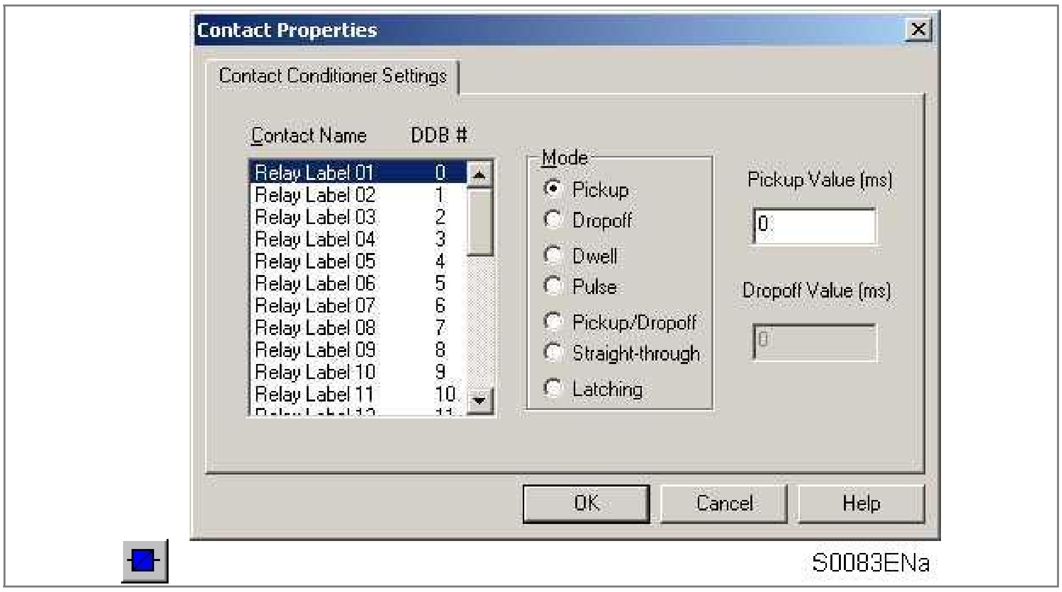
1. Select the **LED name** from the list (only shown when inserting a new symbol).
2. Configure the LED output to be Red, Yellow or Green.
3. Configure a Green LED by driving the Green DDB input.
4. Configure a RED LED by driving the RED DDB input.
5. Configure a Yellow LED by driving the RED and GREEN DDB inputs simultaneously.
6. Configure the LED output to be latching or non-latching.


1
Non - Latching
FnKey LED1 Red
DDB #1040
FnKey LEDGrn
DDB #1041
LED Output Red
1
Non - Latching
FnKey LED1 Red
DDB #1040
FnKey LEDGrn
DDB #1041
LED Output Green
1
Non - Latching
FnKey LED1 Red
DDB #1040
FnKey LEDGrn
DDB #1041
LED Output Yellow

1.6.16 Contact Conditioner Properties

Each contact ■ can be conditioned with an associated timer that can be selected for pick up, drop off, dwell, pulse, pick-up/drop-off, straight-through, or latching operation.

“Straight-through” means it is not conditioned in any way whereas “latching” is used to create a sealed-in or lockout type function.



Contact Properties

Contact Conditioner Settings

Contact Name	DDB #
Relay Label 01	0
Relay Label 02	1
Relay Label 03	2
Relay Label 04	3
Relay Label 05	4
Relay Label 06	5
Relay Label 07	6
Relay Label 08	7
Relay Label 09	8
Relay Label 10	9
Relay Label 11	10

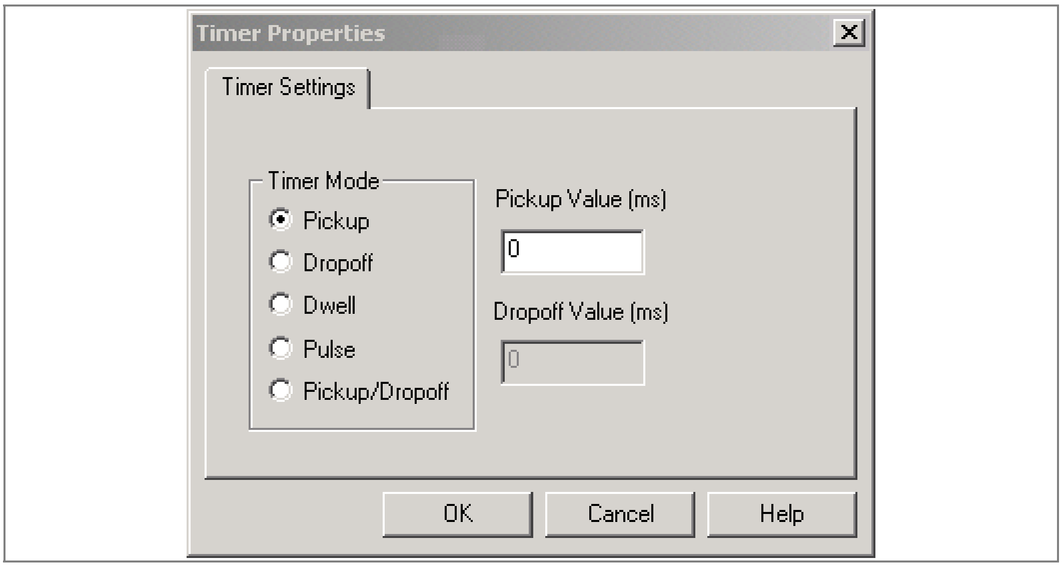
Mode: ● Pickup ○ Dropoff ○ Dwell ○ Pulse ○ Pickup/Dropoff ○ Straight-through ○ Latching

Pickup Value (ms): 0

Dropoff Value (ms): 0

1. Select the contact **name** from the **Contact Name** list (only shown when inserting a new symbol).
2. Choose the conditioner type required in the **Mode** tick list.
3. Set the **Pick-up** Time (in milliseconds), if required.
4. Set the **Drop-off** Time (in milliseconds), if required.

1.6.17 Timer Properties



Timer Properties

Timer Settings

Timer Mode: ● Pickup ○ Dropoff ○ Dwell ○ Pulse ○ Pickup/Dropoff

Pickup Value (ms): 0

Dropoff Value (ms): 0

Each timer ⧄ can be selected for pick up, drop off, dwell, pulse or pick-up/drop-off operation.

1. Choose the operation mode from the **Timer Mode** tick list.
2. Set the Pick-up Time (in milliseconds), if required.
3. Set the Drop-off Time (in milliseconds), if required.

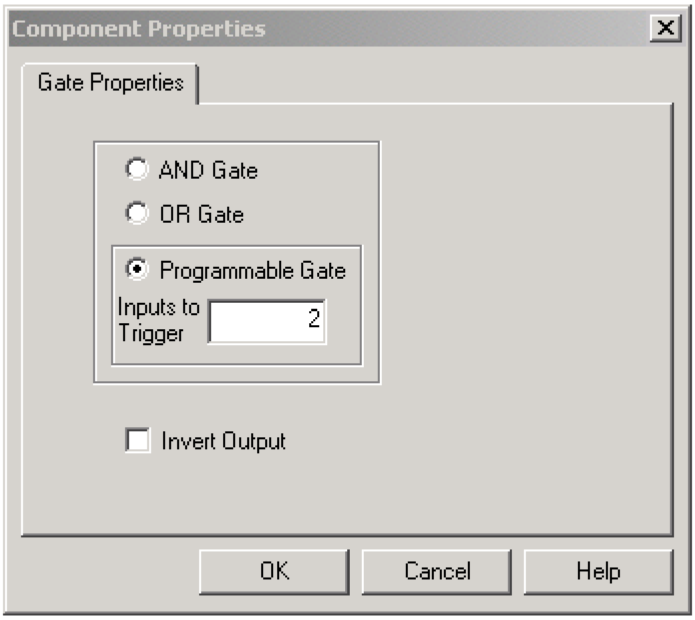
1.6.18 Gate Properties

A Gate may be an **AND**, **OR**, or **Programmable Gate**.

An **AND** gate & requires that all inputs are TRUE for the output to be TRUE.

An **OR** gate 1 requires that one or more input is TRUE for the output to be TRUE.

A **Programmable Gate** ≥ requires that the number of inputs that are TRUE is equal to or greater than its 'Inputs to Trigger' setting for the output to be TRUE.



● Programmable Gate

Inputs to Trigger: 2

☐ Invert Output

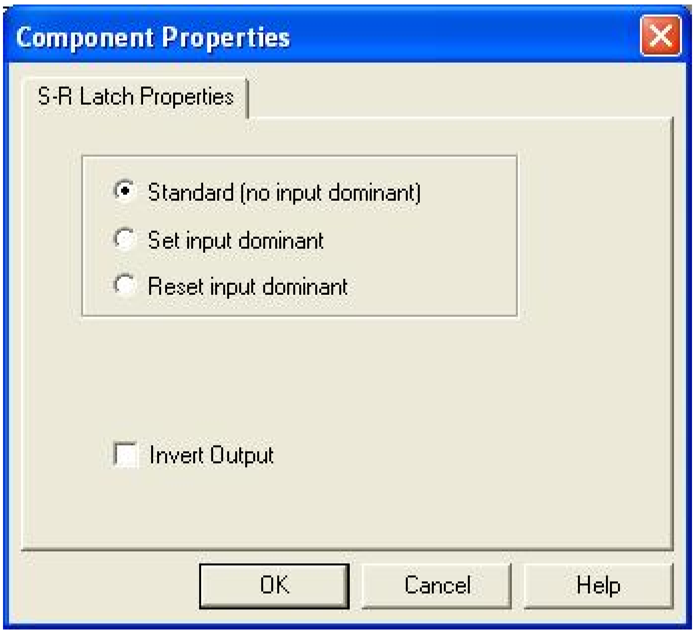
4. Select the Gate type **AND**, **OR**, or **Programmable**.
5. Set the number of inputs to trigger when a Programmable Gate is selected.
6. Select if the output of the gate should be inverted using the Invert Output check box. An inverted output is indicated with a "bubble" on the gate output.

1.6.19 SR Programmable Gate Properties

A **Programmable** SR gate can be selected to operate with these latch properties:

S input	R input	O - Standard	O - Set Input Dominant	O - Rest Input Dominant
0	0	0	0	0
0	1	0	0	0
1	0	1	1	1
1	1	0	1	1

Table 1 - Latch properties



Component Properties

S-R Latch Properties

● Standard (no input dominant)

○ Set input dominant

○ Reset input dominant

☐ Invert Output

Select if the output of the gate should be inverted using the Invert Output check box. An inverted output is indicated with a "bubble" on the gate output.

2 DESCRIPTION OF LOGIC NODES

Note	*Where applicable. Not all nodes appear in every product variant.*

DDB No.	English Text	Source	Description
0	Output Relay 1	Output Conditioner	Assignment of signal to drive output Relay 1
31	Output Relay 32	Output Conditioner	Assignment of signal to drive output Relay 32
32	Opto Input 1	Opto Input	From opto input 1 - when opto energized
47	Opto Input 16	Opto Input	From opto input 16 - when opto energized
55	Opto Input 24	Opto Input	From opto input 24 - when opto energized
63	Opto Input 32	Opto Input	From opto input 32 - when opto energized
64 to 79	Not used		
80	IM Input 1	InterMiCOM	InterMiCOM Input 1 - is driven by a message from the remote line end
87	IM Input 8	InterMiCOM	InterMiCOM Input 8 - is driven by a message from the remote line end
88	IM Output 1	InterMiCOM	InterMiCOM Output 1 - mapping what will be sent to the remote line end
95	IM Output 8	InterMiCOM	InterMiCOM Output 8 - mapping what will be sent to the remote line end
96	IM64 Ch1 Input 1	IM64	IM64 Ch1 Input 1 - is driven by a message from the remote line end
103	IM64 Ch1 Input 8	IM64	IM64 Ch1 Input 8 - is driven by a message from the remote line end
104	IM64 Ch2 Input 1	IM64	IM64 Ch2 Input 1 - is driven by a message from the remote line end
111	IM64 Ch2 Input 8	IM64	IM64 Ch2 Input 8 - is driven by a message from the remote line end
112	IM64 Ch1 Output 1	PSL	IM64 Ch1 Output 1 - mapping what will be sent to the remote line end
119	IM64 Ch1 Output 8	PSL	IM64 Ch1 Output 8 - mapping what will be sent to the remote line end
120	IM64 Ch2 Output 1	PSL	IM64 Ch2 Output 1 - mapping what will be sent to the remote line end
127	IM64 Ch2 Output 8	PSL	IM64 Ch2 Output 8 - mapping what will be sent to the remote line end
128	Relay Cond 1	PSL	Input to Relay 1 Output Conditioner
159	Relay Cond 32	PSL	Input to Relay 32 Output Conditioner
160	Timer in 1	PSL	Input to Auxiliary Timer 1
175	Timer in 16	PSL	Input to Auxiliary Timer 16
176	Timer out 1	Auxiliary Timer	Output from Auxiliary Timer 1
191	Timer out 16	Auxiliary Timer	Output from Auxiliary Timer 16
192	Control Input 1	Control Input Command	Control Input 1 - for SCADA and menu commands into PSL
223	Control Input 32	Control Input Command	Control Input 32 - for SCADA and menu commands into PSL
256	Virtual Output 1	PSL	Virtual Output 1 - allows user to control a binary signal which can be mapped via SCADA protocol output to other devices
287	Virtual Output32	PSL	Virtual Output 32 - allows user to control a binary signal which can be mapped via SCADA protocol output to other devices
288	SG-opto Invalid	Group Selection	Setting group selection opto inputs have detected an invalid (disabled) settings group
289	Prot'n Disabled	Commissioning Test	Protection disabled - typically out of service due to test mode

DDB No.	English Text	Source	Description
290	Static Test Mode	Commissioning Test	Static Test Mode option bypasses the delta phase selectors, power swing detection and reverts to conventional directional line and cross polarization to allow testing with test sets that can not simulate a real fault
291	Test Loopback	IM64	Loopback test in service (external or internal)
292	Test IM64	IM64	Indication that relay is in Test mode
293	VT Fail Alarm	VT Supervision	VTS Indication alarm - failed VT (fuse blow) detected by VT supervision
294	CT Fail Alarm	CT Supervision	CTS Indication Alarm (CT supervision alarm)
295 to 296	Not used		
297	Power Swing	Powerswing Blocking	Powerswing blocking will block any distance zone selected in the setting file
298	CB Fail Alarm	CB Fail	Circuit Breaker Fail Alarm
299	CB Monitor Alarm	CB Monitoring	This alarm indicates that DDB I ^ Maint Alarm (1106) or DDB CB OPs Maint (1108) or DDB CB Time Maint (1110)
300	CB Lockout Alarm	CB Monitoring	This alarm indicates that DDB I ^ Lockout Alarm (1107) or DDB CB OPs Lock (1109) or DDB CB Time lockout (1111)
301	CB Status Alarm	CB Status	Indication of problems by Circuit Breaker state monitoring - example defective auxiliary contacts
302	CB Trip Fail	CB Control	Circuit Breaker Failed to Trip (after a manual/operator) trip command
303	CB Close Fail	CB Control	Circuit Breaker Failed to Close (after a manual/operator or auto-reclose close command)
304	Man CB Unhealthy	CB Control	Manual Circuit Breaker Unhealthy Output signal indicating that the circuit breaker has not closed successfully after a manual close command. (A successful close also requires The Circuit Breaker Healthy signal to reappear within the "healthy window" timeout)
305	No C/S Man Close	CB Control	Indicates that the check synchronism signal has failed to appear for a manual close
306	A/R Lockout	Auto-reclose	Indicates an Auto-reclose Lockout condition - no further auto-reclosures possible until resetting
307	A/R CB Unhealthy	Auto-reclose	Auto-reclose Circuit Breaker unhealthy signal, output from auto-reclose logic. Indicates during auto-reclose in progress, if the Circuit Breaker has to become healthy within the Circuit Breaker Healthy time window
308	A/R No Checksync	Auto-reclose	Indicates during auto-reclose in progress, if system checks have not been satisfied within the Check Synchronizing time window
309	System Split	Check Sync	System Split Alarm - will be raised if the system is split (remains permanently out of synchronism) for the duration of the system split timer
310	Not used		
311	Signaling Fail	IM64	Indicates that the communications signaling needed for the transfer of InterMiCOM^{64} commands has failed. Less good messages were received than expected. The signal describes the state of the receiving channels only, the status of transmission to the remote relay must be determined from the remote relay
312 to 313	Not used		

DDB No.	English Text	Source	Description
314	IM64 SchemeFail		This is relevant to IM64. This is raised when the scheme has failed. In 3 ended there is the passthrough mode where bits can be sent the other way a round the ring if one channel fails to maintain full operation. If 2 channels fail the pass through cannot work and the whole scheme fails hence this alarm. It also applies to 2 ended when 1 channel fails or dual redundant when two channels fail
315	IEEE C37.94 Fail	C Diff	It will appear in case of at least one of the following: CH1 (or CH2) loss of signal, CH1 (or CH2) PATH_YELLOW or CH1 (or CH2) BAD_RX_N
316	Not used		
317	Aid 1 Chan Fail	PSL	Aided channel scheme 1 - Channel Out of service indication, indicating channel failure
318	Aid 2 Chan Fail	PSL	Aided channel scheme 2 - Channel Out of service indication, indicating channel failure
319	F out of Range	Frequency Tracking	Frequency Out of Range Alarm
320	CB2 Fail Alarm	CB2 Fail	Circuit breaker 2 fail alarm
321	CB2 Monitor Alm	CB2 Monitoring	This alarm indicates that DDB CB2 I ^ Maint. Alarm (1113) or DDB CB2 OPs Maint. (1115) or DDB CB2 Time Maint. (1117)
322	CB2 Mon LO Alarm	CB2 Monitoring	This alarm indicates that DDB CB2 I ^ Lockout Alarm (1114) or DDB CB Ops Lock (1116) or DDB CB Time lockout (1118)
323	CB2 Status Alarm	CB2 Status	Indication of problems by circuit breaker 2 state monitoring - example defective auxiliary contacts
324	CB2 Trip Fail	CB2 Control	Circuit breaker 2 failed to trip (after a manual/operator) trip command
325	CB2 Close Fail	CB2 Control	Circuit breaker 2 failed to close (after a manual/operator or auto-reclose close command)
326	Man CB2 Unhealthy	CB2 Control	Manual circuit breaker unhealthy output signal indicating that the circuit breaker 2 has not closed successfully after a manual close command. (A successful close also requires The circuit breaker healthy signal to reappear within the "healthy window" timeout)
327	NoCS CB2ManClose	CB2 Control	Indicates that the check synchronism signal has failed to appear for a manual close
328	AR CB2 Lockout	CB2 Auto-reclose	Indicates an auto-reclose lockout condition - no further auto-reclosures possible until resetting
329	AR CB2 Unhealthy	CB2 Auto-reclose	Auto-reclose circuit breaker unhealthy signal, output from auto-reclose logic. Indicates during auto-reclose in progress, if the circuit breaker has to become healthy within the circuit breaker healthy time window
330	AR CB2 No C/S	CB2 Auto-reclose	Indicates during auto-reclose in progress, if system checks have not been satisfied within the check synchronizing time window
331	Invalid AR Mode	Auto-reclose	AR Mode selected via optos is not supported
332	Not used		
333	InValid Mesg Fmt		Indicates different message length from each end
334	Main Prot. Fail	Co-processor Interface	Indicates a failure in Distance or DEF
335, 336	Not used		
337	Comms Changed	IM64	This is an alarm which indicates that C3794 comms have been changed to standard or vice versa and relay must be rebooted
338	Max Prop Delay	IM64	The propagation delay on either channel 1 or channel 2 exceeds the setting value
339 to 343	Not used		

DDB No.	English Text	Source	Description
344	SR User Alarm 1	PSL	Triggers User Alarm 1 message to be alarmed on LCD display (self-resetting)
347	SR User Alarm 4	PSL	Triggers User Alarm 4 message to be alarmed on LCD display (self-resetting)
348	MR User Alarm 5	PSL	Triggers User Alarm 5 message to be alarmed on LCD display (manual-resetting)
351	MR User Alarm 8	PSL	Triggers User Alarm 8 message to be alarmed on LCD display (manual-resetting)
352	Battery Fail	Self Monitoring	Front panel miniature battery failure - either battery removed from slot, or low voltage
353	Field Volts Fail	Self Monitoring	48V Field Voltage Failure
354	Rear Comm 2 Fail	Self Monitoring	Comm2 hardware failure - second rear communications board
355	GOOSE IED Absent		The IED is not subscribed to a publishing IED in the current scheme
356	NIC Not Fitted		Ethernet board not fitted
357	NIC No Response		Ethernet board not responding
358	NIC Fatal Error		Ethernet board unrecoverable error
359	NIC Soft. Reload		Ethernet problem
360	Bad TCP/IP Cfg.		Ethernet problem
361	Bad OSI Config.		Ethernet problem
362	NIC Link Fail		Ethernet link lost
363	NIC SW Mis-Match		Ethernet board software not compatible with main CPU
364	IP Addr Conflict		The IP address of the IED is already used by another IED
365	IM Loopback	InterMiCOM	EIA(RS)232 InterMiCOM indication that Loopback testing is in progress
366	IM Message Fail	InterMiCOM	EIA(RS)232 InterMiCOM Message Failure alarm. Setting that is used to alarm for poor channel quality. If during the fixed 1.6 s rolling window the ratio of invalid messages to the total number of messages that should be received (based upon the 'Baud Rate' setting) exceeds the above threshold, a 'Message Fail' alarm will be issued
367	IM Data CD Fail	InterMiCOM	EIA(RS)232 InterMiCOM Data Channel Detect Fail i.e. modem failure
368	IM Channel Fail	InterMiCOM	EIA(RS)232 InterMiCOM Channel Failure alarm. No messages were received during the alarm time setting
369	Backup Setting	Self Monitoring	This is an alarm that is ON if any settings fail during the setting changing process. If this happens, the relay will use the last known good setting
370 to 383	Not used		
384	Block Zone 1 Gnd	PSL	Zone 1 Ground basic scheme blocking
385	Block Zone 1 Phs	PSL	Zone 1 Phase basic scheme blocking
386	Block Zone 2 Gnd	PSL	Zone 2 Ground basic scheme blocking
387	Block Zone 2 Phs	PSL	Zone 2 Phase basic scheme blocking
388	Block Zone 3 Gnd	PSL	Zone 3 Ground basic scheme blocking
389	Block Zone 3 Phs	PSL	Zone 3 Phase basic scheme blocking
390	Block Zone P Gnd	PSL	Zone P Ground basic scheme blocking
391	Block Zone P Phs	PSL	Zone P Phase basic scheme blocking
392	Block Zone 4 Gnd	PSL	Zone 4 Ground basic scheme blocking
393	Block Zone 4 Phs	PSL	Zone 4 Phase basic scheme blocking
394	Aid1 InhibitDist	PSL	Block distance aided scheme 1 tripping

DDB No.	English Text	Source	Description
395	Aid1 Inhibit DEF	PSL	Block DEF aided scheme 1 tripping
396	Aid1 Inhibit DIR	PSL	Block Delta directional aided scheme 1 tripping
397	Aid2 InhibitDist	PSL	Block distance aided scheme 2 tripping
398	Aid2 Inhibit DEF	PSL	Block DEF aided scheme 2 tripping
399	Aid2 Inhibit DIR	PSL	Block Delta directional aided scheme 2 tripping
400	Time Synch	PSL	Time Synchronism by Opto pulse
401	I>1 Timer Block	PSL	Block Phase Overcurrent Stage 1 Time delayed tripped trip
402	I>2 Timer Block	PSL	Block Phase Overcurrent Stage 2 Time delayed tripped trip
403	I>3 Timer Block	PSL	Block Phase Overcurrent Stage 3 Time delayed trip
404	I>4 Timer Block	PSL	Block Phase Overcurrent Stage 4 Time delayed trip
405	IN>1 Timer Block	PSL	Block Standby Earth Fault Stage 1 Time delayed trip
406	IN>2 Timer Block	PSL	Block Standby Earth Fault Stage 2 Time delayed trip
407	IN>3 Timer Block	PSL	Block Standby Earth Fault Stage 3 Time delayed trip
408	IN>4 Timer Block	PSL	Block Standby Earth Fault Stage 4 Time delayed trip
409	ISEF>1 Timer Blk	PSL	Block Sensitive Earth Fault Stage 1 Time delayed trip
410	ISEF>2 Timer Blk	PSL	Block Sensitive Earth Fault Stage 2 Time delayed trip
411	ISEF>3 Timer Blk	PSL	Block Sensitive Earth Fault Stage 3 Time delayed trip
412	ISEF>4 Timer Blk	PSL	Block Sensitive Earth Fault Stage 4 Time delayed trip
413	Not used		
414	V<1 Timer Block	PSL	Block Phase Undervoltage Stage 1 Time delayed trip
415	V<2 Timer Block	PSL	Block Phase Undervoltage Stage 2 Time delayed trip
416	V>1 Timer Block	PSL	Block Phase Overvoltage Stage 1 Time delayed trip
417	V>2 Timer Block	PSL	Block Phase Overvoltage Stage 2 Time delayed trip
418	VN>1 Timer Block	PSL	Block Residual Overvoltage Stage 1 Time delayed trip
419	VN>2 Timer Block	PSL	Block Residual Overvoltage Stage 2 Time delayed trip
420	CB(1) Aux 3ph(52-A)	PSL	52-A (CB closed) CB Auxiliary Input (3 phase)
421	CB(1) Aux A(52-A)	PSL	52-A (CB A Phase closed) CB Auxiliary
422	CB(1) Aux B(52-A)	PSL	52-A (CB B Phase closed) CB Auxiliary
423	CB(1) Aux C(52-A)	PSL	52-A (CB C Phase closed) CB Auxiliary
424	CB(1) Aux 3ph(52-B)	PSL	52-B (CB open) CB Auxiliary Input (3 phase)
425	CB(1) Aux A(52-B)	PSL	52-B (CB A Phase open) CB Auxiliary Input
426	CB(1) Aux B(52-B)	PSL	52-B (CB B Phase open) CB Auxiliary Input
427	CB(1) Aux C(52-B)	PSL	52-B (CB C Phase open) CB Auxiliary Input
428	CB2 Aux 3ph(52-A)	PSL	52-A (CB2 closed) CB2 auxiliary input (3 phase)
429	CB2 Aux A(52-A)	PSL	52-A (CB2 A phase closed) CB2 auxiliary
430	CB2 Aux B(52-A)	PSL	52-A (CB2 B phase closed) CB2 auxiliary
431	CB2 Aux C(52-A)	PSL	52-A (CB2 C phase closed)CB2 auxiliary
432	CB2 Aux 3ph(52-B)	PSL	52-B (CB2 open) CB2 auxiliary input (3 phase)
433	CB2 Aux A(52-B)	PSL	52-B (CB2 A phase open) CB2 auxiliary input
434	CB2 Aux B(52-B)	PSL	52-B (CB2 B phase open) CB2 auxiliary input
435	CB2 Aux C(52-B)	PSL	52-B (CB2 C phase open) CB2 auxiliary input
436	CB(1) Healthy	PSL	Circuit Breaker Healthy (input to auto-recloser - that the CB 1 has enough energy to allow re-closing)

DDB No.	English Text	Source	Description
437	CB2 Healthy	PSL	Circuit breaker healthy (input to auto-recloser - that the CB 2 has enough energy to allow re-closing)
438	MCB/VTS	PSL	VT supervision input - signal from external miniature Circuit Breaker showing MCB tripped
439	Trip CB(1)	PSL	Initiate tripping of circuit breaker 1 from a manual command
440	Close CB(1)	PSL	Initiate closing of circuit breaker 1 from a manual command
441	Init Trip CB2	PSL	Initiate tripping of circuit breaker 2 from a manual command
442	Init Close CB2	PSL	Initiate closing of circuit breaker 2 from a manual command
443	Rst CB1 Close Dly	PSL	Reset Manual Circuit Breaker 1 Close Time Delay
444	Reset Relays/LED	PSL	Reset Latched Relays & LEDs (manual reset of any lockout trip contacts, auto-reclose lockout, and LEDs)
445	Reset Thermal	PSL	Reset Thermal State to 0%
446	Reset (CB1) Lockout	PSL	Manual control to reset CB1 auto-recloser from lockout
447	Reset CB(1) Data	PSL	Reset Circuit Breaker Maintenance Values
448	Block CB1 AR	PSL	DDB mapped in PSL from opto or comms input. External signal to force CB1 auto-reclose to lockout
449	Enable 1 pole reclose	PSL	Enable 1 pole reclose from an external input (P443 only)
450	Enable 3 pole reclose	PSL	Enable 3 pole reclose from an external input (P443 only)
451	Pole Discrepancy (CB1)	PSL	Pole Discrepancy (from external detector) - input used to force a 2nd single pole trip to move to a 3 pole auto-reclose cycle
452	Loopback Mode	PSL	To enable loopback mode via opto input
453 to 457	Not used		
458	Inhibit WI	PSL	Inhibit Weak Infeed aided scheme Logic
459	Test Mode	PSL	Commissioning Tests - automatically places relay in Test Mode
460	103 Command Blocking	PSL	For IEC-870-5-103 protocol only, used for "Command Blocking" (relay ignores SCADA commands)
461	103 Monitor Blocking	PSL	For IEC-870-5-103 protocol only, used for "Monitor Blocking" (relay is quiet - issues no messages via SCADA port)
462	Not used		
463	Inhibit I>1	PSL	Inhibit stage 1 overcurrent protection
464	Inhibit I>2	PSL	Inhibit stage 2 overcurrent protection
465	Inhibit I>3	PSL	Inhibit stage 3 overcurrent protection
466	Inhibit I>4	PSL	Inhibit stage 4 overcurrent protection
467	Inhibit IN>1	PSL	Inhibit stage 1 earth fault protection
468	Inhibit IN>2	PSL	Inhibit stage 2 earth fault protection
469	Inhibit IN>3	PSL	Inhibit stage 3 earth fault protection
470	Inhibit IN>4	PSL	Inhibit stage 4 earth fault protection
471	Inhibit V<1	PSL	Inhibit stage 1 undervoltage protection
472	Inhibit V<2	PSL	Inhibit stage 2 undervoltage protection
473	Inhibit V>1	PSL	Inhibit stage 1 overvoltage protection
474	Inhibit V>2	PSL	Inhibit stage 2 overvoltage protection
475	Inhibit VN>1	PSL	Inhibit stage 1 residual overvoltage protection
476	Inhibit VN>2	PSL	Inhibit stage 2 residual overvoltage protection
477	Not used		
478	Inhibit Thermal	PSL	Inhibit thermal overload protection

DDB No.	English Text	Source	Description
479	Inhibit CB Status	PSL	Inhibit Circuit breaker state monitoring (no alarm for defective/stuck auxiliary contact)
480	Inhibit CB Fail	PSL	Inhibit Circuit Breaker Fail protection
481	Inhibit OpenLine	PSL	Broken conductor protection
482	Inhibit VTS	PSL	Inhibit VT supervision (including turn OF MCBs) using PSL
483	Inhibit CTS	PSL	Inhibit CT supervision via PSL
484	InhibitChecksync	PSL	Inhibit checksync
485	Inhibit TOR	PSL	Inhibit trip on reclose (TOR)
486	Inhibit SOTF	PSL	Inhibit switch onto fault (SOTF)
487	Not used		
488	Set SOTF	PSL	To enable SOTF logic by an external pulse. When this input is energized by en external pulse, SOTF becomes enabled during “SOTF Pulse” time setting
489	AR Reset Z1 EXT	Zone 1 Extension Scheme	AR Reset Z1X reach back to Z1 reach in Z1 extension scheme
490	Reset Zone 1 Ext	PSL	Reset Zone Z1X back to Z1 reach using logic input (i.e. case when external AR and Z1 extension scheme are used)
491	Inhibit LoL	PSL	Inhibit Loss of Load scheme function
492	Aided 1 COS/LGS	PSL	Aided 1 Channel out of service signal (COS) or Loss of Guard signal (LGS) in distance unblocking schemes. This signal is normally driven from an opto input on conventional channels or from InterMiCOM
493	Aided1 Scheme Rx	PSL	Aided Channel 1 - External signal received, for input to distance fixed scheme logic
494	Aided 1 Receive	Aided Scheme Logic	Aided Channel 1 - Internal signal received generated in the Signal Receive Logic
495	Not used		
496	Aid1 Block Send	PSL	Prevent sending by customized logic - Aided scheme 1
497	Aid1 Custom Send	PSL	Programmable send logic for special customized scheme (Aided channel 1)
498	Aided 1 Send	Aided Scheme Logic	Aided Channel 1 Send - internal send signal generated in Signal Send Logic
499	Aid1 Custom T In	PSL	When using a custom programmable aided scheme 1, the user is able to include a current reversal guard timer. Energizing this DDB will additionally start this timer, from PSL
500	Aid1 CustomT Out	Aided Scheme Logic	When using customized aided scheme 1, this signal is used to indicate any additional condition that should be treated as permission for an aided trip (for example a permissive signal received could be connected, or a blocking signal could be inverted and then connected)
501	Aid1 Trip Enable	Aided Scheme Logic	Aided Scheme 1 Trip Enable - this is a permissive signal used to accelerate Zone 2, or a blocking signal which has been inverted. It is a signal output, part-way through the internal fixed logic of aided schemes
502	Aid1 Custom Trip	PSL	Aid1 Custom Trip Enable
503	Aid 1 Dist Trip	Aided Scheme Logic	Aided Scheme 1 Distance Trip command (output from Aided tripping logic)
504	Aid 1 Delta Trip	Aided Scheme Logic	Aided Scheme 1 Delta Directional Trip command (output from Aided tripping logic)
505	Aid 1 DEF Trip	Aided Scheme Logic	Aided Scheme 1 DEF Trip command (output from Aided tripping logic)

DDB No.	English Text	Source	Description
506	Aided 2 COS/LGS	PSL	Aided 2 Channel out of service signal (COS) or Loss of Guard signal (LGS) in distance unblocking schemes. This signal is normally driven from an opto input on conventional channels or from InterMiCOM
507	Aided2 Scheme Rx	PSL	Aided Channel 2 - External signal received, for input to distance fixed scheme logic
508	Aided 2 Receive	Aided Scheme Logic	Aided Channel 2 - Internal signal received generated in the Signal Receive Logic
509 to 511	Not used		
512	Aid2 Block Send	PSL	Prevent sending by customized logic - Aided scheme 2
513	Aid2 Custom Send	PSL	Programmable send logic for special customized scheme (Aided channel 2)
514	Aided 2 Send	Aided Scheme Logic	Aided Channel 2 Send - internal send signal generated in Signal Send Logic
515	Aid2 Custom T In	PSL	When using a custom programmable aided scheme 2, the user is able to include a current reversal guard timer. Energizing this DDB will additionally start this timer, from PSL
516	Aid2 CustomT Out	Aided Scheme Logic	When using customized aided scheme 2, this signal is used to indicate any additional condition that should be treated as permission for an aided trip (for example a permissive signal received could be connected, or a blocking signal could be inverted and then connected)
517	Aid2 Trip Enable	Aided Scheme Logic	Aided scheme 2 Trip Enable - this is a permissive signal used to accelerate Zone 2, or a blocking signal which has been inverted. It is a signal output, part-way through the internal fixed logic of aided schemes
518	Aid2 Custom Trip	PSL	Aid2 Custom Trip Enable
519	Aid 2 Dist Trip	Aided Scheme Logic	Aided Scheme 2 Distance Trip command (output from Aided tripping logic)
520	Aid 2 Delta Trip	Aided Scheme Logic	Aided Scheme 2 Delta Directional Trip command (output from Aided tripping logic)
521	Aid 2 DEF Trip	Aided Scheme Logic	Aided scheme 2 DEF Trip command (output from Aided tripping logic)
522	Any Trip	Trip Conversion Logic	Any trip signal - can be used as the trip command in three-pole tripping applications
523	Trip Output A (CB1)	Trip Conversion Logic	Trip signal for phase A - used as a command to drive Trip A output contact(s). Takes the output from the internal trip conversion logic
524	Trip Output B (CB1)	Trip Conversion Logic	Trip signal for phase B - used as a command to drive Trip B output contact(s). Takes the output from the internal trip conversion logic
525	Trip Output C (CB1)	Trip Conversion Logic	Trip signal for phase C - used as a command to drive Trip C output contact(s). Takes the output from the internal trip conversion logic
526	Trip 3ph (CB1)	Trip Conversion Logic	3 Phase Trip command
527	2/3 Ph Fault	Trip Conversion Logic	2 or 3 Phase fault indication - used to flag whether the fault is polyphase. Typically used to control auto-reclose logic, where auto-reclosing is allowed only for single phase faults
528	3 Ph Fault	Trip Conversion Logic	3 Phase Fault indication. Typically used to control auto-reclose logic, where auto-reclosing is blocked for faults affecting all three phases together
529	Trip Inputs 3Ph (CB1)	PSL	Trip 3 Phase - Input to Trip Latching Logic
530	Trip Inputs A	PSL	A Phase Trip - Input to Trip Conversion Logic. Essential to ensure correct single or three pole trip command results (e.g. Converts a 2 pole trip to 3 phase)

DDB No.	English Text	Source	Description
531	Trip Inputs B	PSL	B Phase Trip - Input to Trip Conversion Logic. Essential to ensure correct single or three pole trip command results (e.g. Converts a 2 pole trip to 3 phase)
532	Trip Inputs C	PSL	C Phase Trip - Input to Trip Conversion Logic. Essential to ensure correct single or three pole trip command results (e.g. Converts a 2 pole trip to 3 phase)
533	Force 3Pole Trip	PSL	Force any trip which is issued to always be 3 pole (trip conversion - used in single pole trip applications, to signal when single pole tripping and re-closing is either unwanted, or impossible)
534	External Trip3ph	PSL	External Trip 3 phase - allows external protection to initiate breaker fail, circuit breaker condition monitoring statistics, and internal auto-reclose (if enabled)
535	External Trip A	PSL	External Trip A phase - allows external protection to initiate breaker fail, circuit breaker condition monitoring statistics, and internal auto-reclose (if enabled)
536	External Trip B	PSL	External Trip B phase - allows external protection to initiate breaker fail, circuit breaker condition monitoring statistics, and internal auto-reclose (if enabled)
537	External Trip C	PSL	External Trip C phase - allows external protection to initiate breaker fail, circuit breaker condition monitoring statistics, and internal auto-reclose (if enabled)
538	CB2 Ext Trip3ph	PSL	External trip 3 phase - allows external protection to initiate breaker 2 fail
539	CB2 Ext Trip A	PSL	External trip A phase - allows external protection to initiate breaker 2 fail
540	CB2 Ext Trip B	PSL	External trip B phase - allows external protection to initiate breaker 2 fail
541	CB2 Ext Trip C	PSL	External trip C phase - allows external protection to initiate breaker 2 fail
542	SG Select X1	PSL	Setting Group Selector X1 (low bit)-selects SG2 if only DDB 542 signal is active. SG1 is active if both DDB 542 & DDB 543=0 SG4 is active if both DDB 542 & DDB 543=1
543	SG Select 1X	PSL	Setting Group Selector 1X (high bit)-selects SG3 if only DDB 543 is active. SG1 is active if both DDB 542 & DDB 543=0 SG4 is active if both DDB 542 & DDB 543=1
544	Clear Statistics	PSL	To reset all statistics values cumulated on the relay. If mapped, the input for this signal could come from a command of the remote end (DDB 1020- Clear Stats Cmd-) via IM64
545 to 549	Not used		
550	Inhibit Predictive OST	PSL	Block Predictive Out of Step tripping command
551	Predictive OST	PSL	Predictive Out of Step trip
552	Inhibit OST	PSL	Block Out of Step tripping command
553	OST	PSL	Out of Step trip
554	Start Z5	PSL	Positive sequence impedance is detected in Z5
555	Start Z6	PSL	Positive sequence impedance is detected in Z6
556	CNV Active	Distance Basic Scheme	Level detector Current No Volts (CNV) exceeded
557	TOR Trip CNV	Distance Basic Scheme	Trip on Reclose trip due to Current No Volts (CNV) level detectors

DDB No.	English Text	Source	Description
558	SOTF Trip CNV	Distance Basic Scheme	Switch on to Fault trip due to Current No Volts (CNV) level detectors
559	Fast OV PHA	Distance Basic Scheme	Phase A Fast Overvoltage level detector used by Current No Volts (CNV)
560	Fast OV PHB	Distance Basic Scheme	Phase B Fast Overvoltage level detector used by Current No Volts (CNV)
561	Fast OV PHC	Distance Basic Scheme	Phase C Fast Overvoltage level detector used by Current No Volts (CNV)
562	I2> Inhibit	PSL	Inhibit Neg Sequence overcurrent protection
563	I2>1 Tmr Blk	PSL	Block Neg Sequence overcurrent stage 1 time delayed trip
564	I2>2 Tmr Blk	PSL	Block Neg Sequence overcurrent stage 2 time delayed trip
565	I2>3 Tmr Blk	PSL	Block Neg Sequence overcurrent stage 3 time delayed trip
566	I2>4 Tmr Blk	PSL	Block Neg Sequence overcurrent stage 4 time delayed trip
567	I2>1 Start	Neg Sequence Overcurrent	1st stage Neg Sequence overcurrent start
568	I2>2 Start	Neg Sequence Overcurrent	2nd stage Neg Sequence overcurrent start
569	I2>3 Start	Neg Sequence Overcurrent	3rd stage Neg Sequence overcurrent start
570	I2>4 Start	Neg Sequence Overcurrent	4th stage Neg Sequence overcurrent start
571	I2>1 Trip	Neg Sequence Overcurrent	1st stage Neg Sequence overcurrent trip
572	I2>2 Trip	Neg Sequence Overcurrent	2nd stage Neg Sequence overcurrent trip
573	I2>3 Trip	Neg Sequence Overcurrent	3rd stage Neg Sequence overcurrent trip
574	I2>4 Trip	Neg Sequence Overcurrent	4th stage Neg Sequence overcurrent trip
575	Not used		
576	AR Trip Test	Commissioning Test	Auto-reclose trip test cycle in progress. Indication that a manually-initiated test cycle is in progress
577	AR Trip Test A	Commissioning Test	Auto-reclose trip test A phase. Indication that a manually-initiated test cycle is in progress
578	AR Trip Test B	Commissioning Test	Auto-reclose trip test B phase. Indication that a manually-initiated test cycle is in progress
579	AR Trip Test C	Commissioning Test	Auto-reclose trip test C phase. Indication that a manually-initiated test cycle is in progress
580	AR Init 3Ph	Auto-reclose	Initiate 3 Phase auto-reclose (signal to an external recloser) P443 only
581	Block AR	Auto-Reclose	Block auto-reclose (BAR signal to an external re-closer)
582 to 591	Not used		
592	df/dt> Inhibit	PSL	Inhibit df/dt protection
593	df/dt>1 Tmr Blk	PSL	Block df/dt Stage 1 Timer
594	df/dt>2 Tmr Blk	PSL	Block df/dt Stage 2 Timer
595	df/dt>3 Tmr Blk	PSL	Block df/dt Stage 3 Timer
596	df/dt>4 Tmr Blk	PSL	Block df/dt Stage 4 Timer

DDB No.	English Text	Source	Description
597	df/dt>1 Start	df/dt Protection	df/dt Stage 1 Start
598	df/dt>2 Start	df/dt Protection	df/dt Stage 2 Start
599	df/dt>3 Start	df/dt Protection	df/dt Stage 3 Start
600	df/dt>4 Start	df/dt Protection	df/dt Stage 4 Start
601	df/dt>1 Trip	df/dt Protection	df/dt Stage 1 Trip
602	df/dt>2 Trip	df/dt Protection	df/dt Stage 2 Trip
603	df/dt>3 Trip	df/dt Protection	df/dt Stage 3 Trip
604	df/dt>4 Trip	df/dt Protection	df/dt Stage 4 Trip
605 to 607	Not used		
608	Zone 1 Trip	Distance Basic Scheme	Zone 1 Trip
609	Zone 1 A Trip	Distance Basic Scheme	Zone 1 A Phase Trip
610	Zone 1 B Trip	Distance Basic Scheme	Zone 1 B Phase Trip
611	Zone 1 C Trip	Distance Basic Scheme	Zone 1 C Phase Trip
612	Zone 1 N Trip	Distance Basic Scheme	Zone 1 N Trip
613	Zone 2 Trip	Distance Basic Scheme	Zone 2 Trip
614	Zone 2 A Trip	Distance Basic Scheme	Zone 2 A Phase Trip
615	Zone 2 B Trip	Distance Basic Scheme	Zone 2 B Phase Trip
616	Zone 2 C Trip	Distance Basic Scheme	Zone 2 C Phase Trip
617	Zone 2 N Trip	Distance Basic Scheme	Zone 2 N Trip
618	Zone 3 Trip	Distance Basic Scheme	Zone 3 Trip
619	Zone 3 A Trip	Distance Basic Scheme	Zone 3 A Phase Trip
620	Zone 3 B Trip	Distance Basic Scheme	Zone 3 B Phase Trip
621	Zone 3 C Trip	Distance Basic Scheme	Zone 3 C Phase Trip
622	Zone 3 N Trip	Distance Basic Scheme	Zone 3 N Trip
623	Zone P Trip	Distance Basic Scheme	Zone P Trip
624	Zone P A Trip	Distance Basic Scheme	Zone P A Phase Trip
625	Zone P B Trip	Distance Basic Scheme	Zone P B Phase Trip
626	Zone P C Trip	Distance Basic Scheme	Zone P C Phase Trip
627	Zone P N Trip	Distance Basic Scheme	Zone P N Trip

DDB No.	English Text	Source	Description
628	Zone 4 Trip	Distance Basic Scheme	Zone 4 Trip
629	Zone 4 A Trip	Distance Basic Scheme	Zone 4 A Phase Trip
630	Zone 4 B Trip	Distance Basic Scheme	Zone 4 B Phase Trip
631	Zone 4 C Trip	Distance Basic Scheme	Zone 4 C Phase Trip
632	Zone 4 N Trip	Distance Basic Scheme	Zone 4 N Phase Trip
633	Aided 1 Trip A	Aided Scheme Logic	Aided channel scheme 1 Trip A phase
634	Aided 1 Trip B	Aided Scheme Logic	Aided channel scheme 1 Trip B phase
635	Aided 1 Trip C	Aided Scheme Logic	Aided channel scheme 1 Trip C phase
636	Aided 1 Trip N	Aided Scheme Logic	Aided channel scheme 1 Trip involving ground (N)
637	Aid 1 WI Trip A	Aided Scheme Logic	Aided scheme 1 Weak Infeed Trip phase A
638	Aid 1 WI Trip B	Aided Scheme Logic	Aided scheme 1 Weak Infeed Trip phase B
639	Aid 1 WI Trip C	Aided Scheme Logic	Aided scheme 1 Weak Infeed Trip phase C
640	Aid1 Delta Tr3Ph	Aided Scheme Logic	Aided scheme 1 Delta directional Trip 3 Phase
641	Aid1 DEF Trip3Ph	Aided Scheme Logic	Aided 1 Directional Earth Fault scheme Trip 3 Phase
642	Aid1 WI Trip 3Ph	Aided Scheme Logic	Aided channel scheme 1 - Weak Infeed logic Trip 3 Phase
643	Aided 2 Trip A	Aided Scheme Logic	Aided channel scheme 2 Trip A phase
644	Aided 2 Trip B	Aided Scheme Logic	Aided channel scheme 2 Trip B phase
645	Aided 2 Trip C	Aided Scheme Logic	Aided channel scheme 2 Trip C phase
646	Aided 2 Trip N	Aided Scheme Logic	Aided channel scheme 2 Trip involving ground (N)
647	Aid 2 WI Trip A	Aided Scheme Logic	Aided scheme 2 Weak Infeed Trip phase A
648	Aid 2 WI Trip B	Aided Scheme Logic	Aided scheme 2 Weak Infeed Trip phase B
649	Aid 2 WI Trip C	Aided Scheme Logic	Aided scheme 2 Weak Infeed Trip phase C
650	Aid2 Delta Tr3Ph	Aided Scheme Logic	Aided scheme 2 Delta directional Trip 3 Phase
651	Aid2 DEF Trip3Ph	Aided Scheme Logic	Aided 2 Directional Earth Fault scheme Trip 3 Phase
652	Aid2 WI Trip 3Ph	Aided Scheme Logic	Aided channel scheme 2 - Weak Infeed logic Trip 3 Phase
653	Not used		

DDB No.	English Text	Source	Description
654	Loss of Load Trip	Loss of Load Logic	Loss of Load Trip
655	I>1 Trip	Overcurrent	1st Stage phase overcurrent Trip 3 phase
656	I>1 Trip A	Overcurrent	1st Stage phase overcurrent Trip phase A
657	I>1 Trip B	Overcurrent	1st Stage phase overcurrent Trip phase B
658	I>1 Trip C	Overcurrent	1st Stage phase overcurrent Trip phase C
659	I>2 Trip	Overcurrent	2nd Stage phase overcurrent Trip 3 phase
660	I>2 Trip A	Overcurrent	2nd Stage phase overcurrent Trip phase A
661	I>2 Trip B	Overcurrent	2nd Stage phase overcurrent Trip phase B
662	I>2 Trip C	Overcurrent	2nd Stage phase overcurrent Trip phase C
663	I>3 Trip	Overcurrent	3rd Stage phase overcurrent Trip 3 phase
664	I>3 Trip A	Overcurrent	3rd Stage phase overcurrent Trip phase A
665	I>3 Trip B	Overcurrent	3rd Stage phase overcurrent Trip phase B
666	I>3 Trip C	Overcurrent	3rd Stage phase overcurrent Trip phase C
667	I>4 Trip	Overcurrent	4th Stage phase overcurrent Trip 3 phase
668	I>4 Trip A	Overcurrent	4th Stage phase overcurrent Trip phase A
669	I>4 Trip B	Overcurrent	4th Stage phase overcurrent Trip phase B
670	I>4 Trip C	Overcurrent	4th Stage phase overcurrent Trip phase C
671	IN>1 Trip	Earth Fault	1st Stage Stand By Earth Fault (SBEF) protection Trip
672	IN>2 Trip	Earth Fault	2nd Stage Stand By Earth Fault (SBEF) protection Trip
673	IN>3 Trip	Earth Fault	3rd Stage Stand By Earth Fault (SBEF) protection Trip
674	IN>4 Trip	Earth Fault	4th Stage Stand By Earth Fault (SBEF) protection Trip
675	ISEF>1 Trip	Sensitive Earth Fault	1st Stage Sensitive Earth Fault (SEF) protection Trip
676	ISEF>2 Trip	Sensitive Earth Fault	2nd Stage Sensitive Earth Fault (SEF) protection Trip
677	ISEF>3 Trip	Sensitive Earth Fault	3rd Stage Sensitive Earth Fault (SEF) protection Trip
678	ISEF>4 Trip	Sensitive Earth Fault	4th Stage Sensitive Earth Fault (SEF) protection Trip
679	Broken Wire Trip	Broken Conductor	Broken Conductor Trip
680	Thermal Trip	Thermal overload	Thermal Overload Trip
681	Not used		
682	IREF> Trip	Sensitive Earth Fault	Restricted Earth Fault (REF) protection trip
683	V<1 Trip	Undervoltage	Undervoltage stage 1, three Phase Trip
684	V<1 Trip A/AB	Undervoltage	Undervoltage stage 1 A/AB Phase Trip
685	V<1 Trip B/BC	Undervoltage	Undervoltage stage 1 B/BC Phase Trip
686	V<1 Trip C/CA	Undervoltage	Undervoltage stage 1 C/CA Phase Trip
687	V<2 Trip	Undervoltage	Undervoltage stage 2, three Phase Trip
688	V<2 Trip A/AB	Undervoltage	Undervoltage stage 2 A/AB Phase Trip
689	V<2 Trip B/BC	Undervoltage	Undervoltage stage 2 B/BC Phase Trip
690	V<2 Trip C/CA	Undervoltage	Undervoltage stage 2 C/CA Phase Trip
691	V>1 Trip	Overvoltage	Overvoltage stage 1, three Phase Trip

DDB No.	English Text	Source	Description
692	V>1 Trip A/AB	Overvoltage	Overvoltage stage 1 A/AB Phase Trip
693	V>1 Trip B/BC	Overvoltage	Overvoltage stage 1 B/BC Phase Trip
694	V>1 Trip C/CA	Overvoltage	Overvoltage stage 1 C/CA Phase Trip
695	V>2 Trip	Overvoltage	Overvoltage stage 2, three Phase Trip
696	V>2 Trip A/AB	Overvoltage	Overvoltage stage 2 A/AB Phase Trip
697	V>2 Trip B/BC	Overvoltage	Overvoltage stage 2 B/BC Phase Trip
698	V>2 Trip C/CA	Overvoltage	Overvoltage stage 2 C/CA Phase Trip
699	Pole Discrepancy (CB1)	Pole discrepancy	Pole Discrepancy signal to force a three pole trip conversion, if the relay detects one pole dead, and no Auto-reclose in Progress
700	VN>1 Trip	Residual Overvoltage	Residual Overvoltage stage 1 Trip
701	VN>2 Trip	Residual Overvoltage	Residual Overvoltage stage 2 Trip
702	Fault REC TRIG	PSL	Trigger for Fault Recorder
703	Not used		
704	TOR Trip Zone 1	Trip on Close	TOR Trip Zone 1 (Trip on Reclose)
705	TOR Trip Zone 2	Trip on Close	TOR Trip Zone 2
706	TOR Trip Zone 3	Trip on Close	TOR Trip Zone 3
707	TOR Trip Zone 4	Trip on Close	TOR Trip Zone 4
708	TOR Trip Zone P	Trip on Close	TOR Trip Zone P
709	SOTF Trip Zone 1	Trip on Close	SOTF Trip Zone 1 (Switch On To Fault)
710	SOTF Trip Zone 2	Trip on Close	SOTF Trip Zone 2
711	SOTF Trip Zone 3	Trip on Close	SOTF Trip Zone 3
712	SOTF Trip Zone 4	Trip on Close	SOTF Trip Zone 4
713	SOTF Trip Zone P	Trip on Close	SOTF Trip Zone P
714 to 735	Not used		
736	Any Start		Any Start
737 to 740	Not used		
741	Zone 1 A Start	Distance Basic Scheme	Zone 1 A Phase Start
742	Zone 1 B Start	Distance Basic Scheme	Zone 1 B Phase Start
743	Zone 1 C Start	Distance Basic Scheme	Zone 1 C Phase Start
744	Zone 1 N Start	Distance Basic Scheme	Zone 1 Ground element Start
745	Zone 2 A Start	Distance Basic Scheme	Zone 2 A Phase Start
746	Zone 2 B Start	Distance Basic Scheme	Zone 2 B Phase Start
747	Zone 2 C Start	Distance Basic Scheme	Zone 2 C Phase Start
748	Zone 2 N Start	Distance Basic Scheme	Zone 2 Ground element Start
749	Zone 3 A Start	Distance Basic Scheme	Zone 3 A Phase Start

DDB No.	English Text	Source	Description
750	Zone 3 B Start	Distance Basic Scheme	Zone 3 B Phase Start
751	Zone 3 C Start	Distance Basic Scheme	Zone 3 C Phase Start
752	Zone 3 N Start	Distance Basic Scheme	Zone 3 N Start
753	Zone P A Start	Distance Basic Scheme	Zone P A Phase Start
754	Zone P B Start	Distance Basic Scheme	Zone P B Phase Start
755	Zone P C Start	Distance Basic Scheme	Zone P C Phase Start
756	Zone P N Start	Distance Basic Scheme	Zone P N Start
757	Zone 4 A Start	Distance Basic Scheme	Zone 4 A Phase Start
758	Zone 4 B Start	Distance Basic Scheme	Zone 4 B Phase Start
759	Zone 4 C Start	Distance Basic Scheme	Zone 4 C Phase Start
760	Zone 4 N Start	Distance Basic Scheme	Zone 4 N Start
761	I>1 Start	Overcurrent	1st Stage Overcurrent Start 3 phase
762	I>1 Start A	Overcurrent	1st Stage Overcurrent Start phase A
763	I>1 Start B	Overcurrent	1st Stage Overcurrent Start phase B
764	I>1 Start C	Overcurrent	1st Stage Overcurrent Start phase C
765	I>2 Start	Overcurrent	2nd Stage Overcurrent Start 3 phase
766	I>2 Start A	Overcurrent	2nd Stage Overcurrent Start phase A
767	I>2 Start B	Overcurrent	2nd Stage Overcurrent Start phase B
768	I>2 Start C	Overcurrent	2nd Stage Overcurrent Start phase C
769	I>3 Start	Overcurrent	3rd Stage Overcurrent Start 3 phase
770	I>3 Start A	Overcurrent	3rd Stage Overcurrent Start phase A
771	I>3 Start B	Overcurrent	3rd Stage Overcurrent Start phase B
772	I>3 Start C	Overcurrent	3rd Stage Overcurrent Start phase C
773	I>4 Start	Overcurrent	4th Stage Overcurrent Start 3 phase
774	I>4 Start A	Overcurrent	4th Stage Overcurrent Start phase A
775	I>4 Start B	Overcurrent	4th Stage Overcurrent Start phase B
776	I>4 Start C	Overcurrent	4th Stage Overcurrent Start phase C
777	IN>1 Start	Earth Fault	1st Stage Stand By Earth Fault (SBEF) overcurrent Start
778	IN>2 Start	Earth Fault	2nd Stage Stand By Earth Fault (SBEF) overcurrent Start
779	IN>3 Start	Earth Fault	3rd Stage Stand By Earth Fault (SBEF) overcurrent Start
780	IN>4 Start	Earth Fault	4th Stage Stand By Earth Fault (SBEF) overcurrent Start
781	ISEF>1 Start	Sensitive Earth Fault	1st Stage Sensitive Earth Fault (SEF) overcurrent Start
782	ISEF>2 Start	Sensitive Earth Fault	2nd Stage Sensitive Earth Fault (SEF) overcurrent Start
783	ISEF>3 Start	Sensitive Earth Fault	3rd Stage Sensitive Earth Fault (SEF) overcurrent Start

DDB No.	English Text	Source	Description
784	ISEF>4 Start	Sensitive Earth Fault	4th Stage Sensitive Earth Fault (SEF) overcurrent Start
785	Thermal Alarm	Thermal Overload	Thermal Overload Alarm
786, 787	Not used		
788	V<1 Start	Undervoltage	Undervoltage stage 1, three Phase Start
789	V<1 Start A/AB	Undervoltage	Undervoltage stage 1, A Phase Start
790	V<1 Start B/BC	Undervoltage	Undervoltage stage 1, B Phase Start
791	V<1 Start C/CA	Undervoltage	Undervoltage stage 1, C Phase Start
792	V<2 Start	Undervoltage	Undervoltage stage 2, three Phase Start
793	V<2 Start A/AB	Undervoltage	Undervoltage stage 2, A Phase Start
794	V<2 Start B/BC	Undervoltage	Undervoltage stage 2, B Phase Start
795	V<2 Start C/CA	Undervoltage	Undervoltage stage 2, C Phase Start
796	V>1 Start	Overvoltage	Overvoltage stage 1, three Phase Start
797	V>1 Start A/AB	Overvoltage	Overvoltage stage 1, A Phase Start
798	V>1 Start B/BC	Overvoltage	Overvoltage stage 1, B Phase Start
799	V>1 Start C/CA	Overvoltage	Overvoltage stage 1, C Phase Start
800	V>2 Start	Overvoltage	Overvoltage stage 2, three Phase Start
801	V>2 Start A/AB	Overvoltage	Overvoltage stage 2, A Phase Start
802	V>2 Start B/BC	Overvoltage	Overvoltage stage 2, B Phase Start
803	V>2 Start C/CA	Overvoltage	Overvoltage stage 2, C Phase Start
804	VN>1 Start	Residual Overvoltage	Residual Overvoltage stage 1 Start
805	VN>2 Start	Residual Overvoltage	Residual Overvoltage stage 2 Start
806 to 828	Not used		
829	VA< start	Poledead	Phase A Under Voltage level detector used in the pole dead logic. Detectors have a fixed threshold: Undervoltage pickup 38.1V-drop off 43.8 V
830	VB< start	Poledead	Phase B Under Voltage level detector used in the pole dead logic. Detectors have a fixed threshold: Undervoltage pickup 38.1V-drop off 43.8 V
831	VC< start	Poledead	Phase C Under Voltage level detector used in the pole dead logic. Detectors have a fixed threshold: Undervoltage pickup 38.1V-drop off 43.8 V
832	VTS Fast Block	VT Supervision	VT Supervision Fast Block - blocks elements which would otherwise mal-operate immediately a fuse failure event occurs
833	VTS Slow Block	VT Supervision	VT Supervision Slow Block - blocks elements which would otherwise mal-operate some time after a fuse failure event occurs
834	Bfail1 Trip 3ph (CB1)	CB Fail	tBF1 Trip 3Ph - three phase output from circuit breaker failure logic, stage 1
835	Bfail2 Trip 3ph (CB1)	CB Fail	tBF2 Trip 3Ph - three phase output from circuit breaker failure logic, stage 2
836	CB2 Fail1 Trip	CB Fail	tBF1 trip 3Ph - three phase output from circuit breaker failure 2 logic, stage 1
837	CB2 Fail2 Trip	CB Fail	tBF2 trip 3Ph - three phase output from circuit breaker failure 2 logic, stage 2

DDB No.	English Text	Source	Description
838	Control Trip (CB1)	CB Control	Control Trip - operator trip instruction to the circuit breaker, via menu, or SCADA. (Does not operate for protection element trips)
839	Control Close (CB1)	CB Control	Control Close command to the circuit breaker. Operates for a manual close command (menu, SCADA), and additionally is driven by the auto-reclose close command
840	Control Trip CB2	CB Control	Control trip - operator trip instruction to the circuit breaker 2, via menu, or SCADA. (Does not operate for protection element trips)
841	Control Close CB2	CB Control	Control close command to the circuit breaker 2. Operates for a manual close command (menu, SCADA)
842	Close in Prog (CB1)	CB Control	Control Close in Progress - the relay has been given an instruction to close the circuit breaker, but the Manual Close timer Delay has not yet finished timing out
843	Block Main Prot	Auto-reclose	Auto-reclose Block Main Protection
844	AR 3pole in prog (CB1)	Auto-reclose	Auto Reclose 3 pole in Progress (dead time is running)
845	AR 1pole in prog (CB1)	Auto-reclose	Single pole auto-reclose in progress (dead time is running)
846	Seq Counter = 0	Auto-reclose	Auto-reclose sequence counter is at zero - no previous faults have been cleared within recent history. The sequence count is at zero because no reclaim times are timing out, and the auto-recloser is not locked out. The re-closer is awaiting the first protection trip, and all programmed cycles are free to follow
847	Seq Counter = 1	Auto-reclose	The first fault trip has happened in a new auto-reclose sequence. Dead time 1, or reclaim time 1 are in the process of timing out
848	Seq Counter = 2	Auto-reclose	Auto-reclose sequence counter is at 2. This means that the initial fault trip happened, and then another trip followed, moving the counter on to 2
849	Seq Counter = 3	Auto-reclose	Auto-reclose sequence counter is at 3. This means that the initial fault trip happened, and then 2 trips followed, moving the counter on to 3
850	Seq Counter = 4	Auto-reclose	Auto-reclose sequence counter is at 4. This means that the initial fault trip happened, and then 3 trips followed, moving the counter on to 4
851	Hidden		
852	Successful Close (CB1)	Auto-reclose	Successful Re-closure indication. The circuit breaker was reclosed by the AR function, and stayed closed. This indication is raised at the expiry of the reclaim time
853	Dead T in Prog	Auto-Reclose	Auto-reclose dead time in progress
854	Auto Close (CB1)	Auto-reclose	Auto-reclose command to the circuit breaker
855	CB2 AR 1p InProg		
856	A/R Status 3P	Auto-reclose	3 Pole Auto-recloser In Service - the auto-reclose function has been enabled either in the relay menu, or by an opto input P443 Only
857	AR Status 1P	Auto-reclose	Single Pole Auto-recloser In Service - the auto-reclose function has been enabled either in the relay menu, or by an opto input P443 Only
858	AR Force CB1 3P	Auto-reclose	This DDB is set when the auto-reclose logic has determined that single pole tripping/auto-reclosing is not permitted for CB1. It can be applied in PSL when required to force trip conversion logic for internal and/or external protection to three phase trip mode for CB1
859	AR Blocked	Auto-reclose	It indicates that AR has been blocked (ex. from external input BAR)
860	Lockout Alarm (CB1)	CB Control	Composite Lockout Alarm - circuit breaker locked out due to auto-recloser, or condition monitoring reasons

DDB No.	English Text	Source	Description
861 to 863	Not used		
864	IA< Start	Undercurrent	A phase undercurrent level detector pickup (detects low current). It is used for breaker failure and also it is used for fault record reset
865	IB< Start	Undercurrent	B phase undercurrent level detector pickup (detects low current). It is used for breaker failure and also it is used for fault record reset
866	IC< Start	Undercurrent	C phase undercurrent level detector pickup (detects low current). It is used for breaker failure and also it is used for fault record reset
867	CB1 IA< Start	Undercurrent	A phase undercurrent level detector pickup (detects low current in CT1). It is used for breaker failure in models with two CT inputs P446 Only
868	CB1 IB< Start	Undercurrent	B phase undercurrent level detector pickup (detects low current in CT1). It is used for breaker failure in models with two CT inputs P446 Only
869	CB1 IC< Start	Undercurrent	C phase undercurrent level detector pickup (detects low current in CT1). It is used for breaker failure in models with two CT inputs P446 Only
870	CB2 IA< Start	Undercurrent	A phase undercurrent level detector pickup (detects low current in CT2). It is used for breaker failure in models with two CT inputs P446 Only
871	CB2 IB< Start	Undercurrent	B phase undercurrent level detector pickup (detects low current in CT2). It is used for breaker failure in models with two CT inputs P446 Only
872	CB2 IC< Start	Undercurrent	C phase undercurrent level detector pickup (detects low current in CT2). It is used for breaker failure in models with two CT inputs P446 Only
873	ISEF< Start	Undercurrent	SEF undercurrent level detector pickup (detects low current in CT SEF)
874 to 875	Not used		
876	Z1X Active	Zone 1 Extension Scheme	Zone 1 extension active - zone 1 is operating in its reach extended mode
877	TOC Active	Trip on Close	Trip on Close functions (either SOTF or TOR) active. These elements are in-service for a period of time following circuit breaker closure
878	TOR Active	Trip on Close	Trip on Reclose protection is active - indicated TOC delay timer has elapsed after circuit breaker opening, and remains in-service on auto-reclosure for the duration of the Trip on Close window
879	SOTF Active	Trip on Close	Switch on to Fault protection is active - in service on manual breaker closure, and then remains in-service for the duration of the Trip on Close window
880	SysChks Inactive (CB1)	Check Sync	System Checks Inactive (output from the check synchronism, and other voltage checks)
881	CS1 Enabled (CB1)	PSL	Check Sync. Stage 1 Enabled
882	CS2 Enabled (CB1)	PSL	Check Sync. Stage 2 Enabled
883	Check Sync 1 OK (CB1)	Check Sync	Check Sync. Stage 1 OK
884	Check Sync 2 OK (CB1)	Check Sync	Check Sync. Stage 2 OK
885	SysSplit Enabled	PSL	System Split function Enabled P443 Only
886	Live Bus (CB1)	Voltage Monitoring	Indicates Live Bus condition is detected

DDB No.	English Text	Source	Description
887	Dead Bus (CB1)	Voltage Monitoring	Indicates Dead Bus condition is detected
888	Live Line	Voltage Monitoring	Indicates Live Line condition is detected
889	Dead Line	Voltage Monitoring	Indicates Dead Line condition is detected
890	All Poles Dead	Pole Dead Logic	Pole dead logic detects 3 phase breaker open
891	Any Pole Dead	Pole Dead Logic	Pole dead logic detects at least one breaker pole open
892	Pole Dead A	Pole Dead Logic	Phase A Pole Dead
893	Pole Dead B	Pole Dead Logic	Phase B Pole Dead
894	Pole Dead C	Pole Dead Logic	Phase C Pole Dead
895	VTS Acc Ind	Fixed logic	Input to accelerate the VTS indication
896	VTS Volt Dep	Fixed logic	VTS signal to voltage dependent functions
897	AR Check Sync OK	PSL	Input to the auto-reclose logic to indicate system in synchronism
898	Ctl Check Sync	PSL	Input to the Circuit Breaker Control Logic to indicate manual check synchronization conditions are satisfied
899	AR Sys Checks OK	PSL	Input to the auto-reclose logic to indicate system checks conditions are satisfied
900	CB1 Ext CS OK	Check sync	External check-sync is OK for CB1
901	CB2 Ext CS OK	Check sync	External check-sync is OK for CB1
902	Not used		
903	CB(1) Open 3 ph	CB Status	Circuit Breaker is Open, all three phases
904	CB(1) Open A ph	CB Status	Circuit Breaker A phase is Open
905	CB(1) Open B ph	CB Status	Circuit Breaker A phase is Open
906	CB(1) Open C ph	CB Status	Circuit Breaker A phase is Open
907	CB(1) Closed 3 ph	CB Status	Circuit Breaker is Closed, all three phases
908	CB(1) Closed A ph	CB Status	Circuit Breaker A phase is Closed
909	CB(1) Closed B ph	CB Status	Circuit Breaker B phase is Closed
910	CB(1) Closed C ph	CB Status	Circuit Breaker C phase is Closed
911	CB2 Open 3 ph	CB Status	Circuit breaker 2 is open, all three phases
912	CB2 Open A ph	CB Status	Circuit breaker 2 A phase is open
913	CB2 Open B ph	CB Status	Circuit breaker 2 A phase is open
914	CB2 Open C ph	CB Status	Circuit breaker 2 A phase is open
915	CB2 Closed 3 ph	CB Status	Circuit breaker 2 is closed, all three phases
916	CB2 Closed A ph	CB Status	Circuit breaker 2 A phase is closed
917	CB2 Closed B ph	CB Status	Circuit breaker 2 B phase is closed
918	CB2 Closed C ph	CB Status	Circuit breaker 2 C phase is closed
919	Inhibit Cmp V1>1	PSL	Inhibit the first stage compensated overvoltage element
920	Inhibit Cmp V1>2	PSL	Inhibit the second stage compensated overvoltage element
921	Cmp V1>1 Tim Blk	PSL	Block the first stage compensated overvoltage element
922	Cmp V1>2 Tim Blk	PSL	Block the second stage compensated overvoltage element
923	V1>1 Cmp Start	Overvoltage	1st stage compensated overvoltage start signal
924	V1>2 Cmp Start	Overvoltage	2nd stage compensated overvoltage start signal
925	V1>1 Cmp Trip	Overvoltage	1st stage compensated overvoltage trip signal
926	V1>2 Cmp Trip	Overvoltage	2nd stage compensated overvoltage trip signal

DDB No.	English Text	Source	Description
927	Not used		
928	CTS Block	CTS	Used to block protection such as Earth Fault if CT problem is detected
929 to 951	Not used		
952	Faulted Phase A	PSL	Faulted Phase A - must be assigned, as this sets the start flag used in records, and on the LCD display
953	Faulted Phase B	PSL	Faulted Phase B - must be assigned, as this sets the start flag used in records, and on the LCD display
954	Faulted Phase C	PSL	Faulted Phase C - must be assigned, as this sets the start flag used in records, and on the LCD display
955	Faulted Phase N	PSL	Faulted Phase N (fault involves ground) - must be assigned, as this sets the start flag used in records, and on the LCD display
956	Started Phase A	PSL	Started Phase A - must be assigned, as this sets the start flag used in records, and on the LCD display
957	Started Phase B	PSL	Started Phase B - must be assigned, as this sets the start flag used in records, and on the LCD display
958	Started Phase C	PSL	Started Phase C - must be assigned, as this sets the start flag used in records, and on the LCD display
959	Started Phase N	PSL	Started Phase N (fault involves ground) - must be assigned, as this sets the start flag used in records, and on the LCD display
960	Zone1 AN Element	Distance Elements	Zone 1 AN ground fault Element
961	Zone1 BN Element	Distance Elements	Zone 1 BN ground fault Element
962	Zone1 CN Element	Distance Elements	Zone 1 CN ground fault Element
963	Zone1 AB Element	Distance Elements	Zone 1 AB phase fault Element
964	Zone1 BC Element	Distance Elements	Zone 1 BC phase fault Element
965	Zone1 CA Element	Distance Elements	Zone 1 CA phase fault Element
966	Zone2 AN Element	Distance Elements	Zone 2 AN ground fault Element
967	Zone2 BN Element	Distance Elements	Zone 2 BN ground fault Element
968	Zone2 CN Element	Distance Elements	Zone 2 CN ground fault Element
969	Zone2 AB Element	Distance Elements	Zone 2 AB phase fault Element
970	Zone2 BC Element	Distance Elements	Zone 2 BC phase fault Element
971	Zone2 CA Element	Distance Elements	Zone 2 CA phase fault Element
972	Zone3 AN Element	Distance Elements	Zone 3 AN ground fault Element
973	Zone3 BN Element	Distance Elements	Zone 3 BN ground fault Element
974	Zone3 CN Element	Distance Elements	Zone 3 CN ground fault Element

DDB No.	English Text	Source	Description
975	Zone3 AB Element	Distance Elements	Zone 3 AB phase fault Element
976	Zone3 BC Element	Distance Elements	Zone 3 BC phase fault Element
977	Zone3 CA Element	Distance Elements	Zone 3 CA phase fault Element
978	ZoneP AN Element	Distance Elements	Zone P AN ground fault Element
979	ZoneP BN Element	Distance Elements	Zone P BN ground fault Element
980	ZoneP CN Element	Distance Elements	Zone P CN ground fault Element
981	ZoneP AB Element	Distance Elements	Zone P AB phase fault Element
982	ZoneP BC Element	Distance Elements	Zone P BC phase fault Element
983	ZoneP CA Element	Distance Elements	Zone P CA phase fault Element
984	Zone4 AN Element	Distance Elements	Zone 4 AN ground fault Element
985	Zone4 BN Element	Distance Elements	Zone 4 BN ground fault Element
986	Zone4 CN Element	Distance Elements	Zone 4 CN ground fault Element
987	Zone4 AB Element	Distance Elements	Zone 4 AB phase fault Element
988	Zone4 BC Element	Distance Elements	Zone 4 BC phase fault Element
989	Zone4 CA Element	Distance Elements	Zone 4 CA phase fault Element
990 to 995	Not used		
996	DEF Forward	Directional Earth Fault	DEF Forward (directional earth fault aided scheme detector)
997	DEF Reverse	Directional Earth Fault	DEF Reverse (directional earth fault aided scheme detector)
998	Delta Dir FWD AN	Delta Directional Element	Delta Directional scheme Forward AN detection
999	Delta Dir FWD BN	Delta Directional Element	Delta Directional scheme Forward BN detection
1000	Delta Dir FWD CN	Delta Directional Element	Delta Directional scheme Forward CN detection
1001	Delta Dir FWD AB	Delta Directional Element	Delta Directional scheme Forward AB detection
1002	Delta Dir FWD BC	Delta Directional Element	Delta Directional scheme Forward BC detection
1003	Delta Dir FWD CA	Delta Directional Element	Delta Directional scheme Forward CA detection
1004	Delta Dir Rev AN	Delta Directional Element	Delta Directional scheme Reverse AN detection

DDB No.	English Text	Source	Description
1005	Delta Dir Rev BN	Delta Directional Element	Delta Directional scheme Reverse BN detection
1006	Delta Dir Rev CN	Delta Directional Element	Delta Directional scheme Reverse CN detection
1007	Delta Dir Rev AB	Delta Directional Element	Delta Directional scheme Reverse AB detection
1008	Delta Dir Rev BC	Delta Directional Element	Delta Directional scheme Reverse BC detection
1009	Delta Dir Rev CA	Delta Directional Element	Delta Directional scheme Reverse CA detection
1010	Phase Select A	Phase Selector	Phase Selector - phase A pickup
1011	Phase Select B	Phase Selector	Phase Selector - phase B pickup
1012	Phase Select C	Phase Selector	Phase Selector - phase C pickup
1013	Phase Select N	Phase Selector	Phase Selector - Neutral indication
1014	P Swing Detector	Powerswing Blocking	Power Swing Detected
1015	PSB Fault	Powerswing Blocking	Power Swing Block Fault
1016	I(2)/I(1)> A	Inrush Detector	2nd Harmonic current ratio exceeds threshold on phase A (may be used to block any instantaneous distance elements that reach through the reactance of a power transformer)
1017	I(2)/I(1)> B	Inrush Detector	2nd Harmonic current ratio exceeds threshold on phase B (may be used to block any instantaneous distance elements that reach through the reactance of a power transformer)
1018	I(2)/I(1)> C	Inrush Detector	2nd Harmonic current ratio exceeds threshold on phase C (may be used to block any instantaneous distance elements that reach through the reactance of a power transformer)
1019	I(2)/I(1)> N	Inrush Detector	2nd Harmonic current ratio exceeds threshold on Neutral current measurement (may be used to block any instantaneous distance elements that reach through the reactance of a power transformer)
1020	Clear Stats Cmd	PSL	This is an indication of the command “Clear Statistics” available in the PSL. This DDB could be used to reset statistics at the remote end (via IM64) by linking it to DDB 544 -Clear Statistics- at the remote end
1021 to 1023	Not used		
1024	LED1 Red	Output Conditioner	Programmable LED 1 Red is energized
1025	LED1 Grn.	Output Conditioner	Programmable LED 1 Green is energized
1038	LED8 Red	Output Conditioner	Programmable LED 8 Red is energized
1039	LED8 Grn.	Output Conditioner	Programmable LED 8 Green is energized
1040	FnKey LED1 Red	Output Conditioner	Programmable Function Key LED 1 Red is energized
1041	FnKey LED1 Grn.	Output Conditioner	Programmable Function Key LED 1 Green is energized
1058	FnKey LED10 Red	Output Conditioner	Programmable Function Key LED 10 Red is energized
1059	FnKey LED10 Grn.	Output Conditioner	Programmable Function Key LED 10 Green is energized

DDB No.	English Text	Source	Description
1060	LED1 Con R	PSL	Assignment of input signal to drive output LED 1 Red
1061	LED1 Con G	PSL	Assignment of signal to drive output LED 1 Green. To drive LED 1 Yellow DDB 676 and DDB 677 must be driven at the same time
1074	LED8 Con R	PSL	Assignment of signal to drive output LED 8 Red
1075	LED8 Con G	PSL	Assignment of signal to drive output LED 8 Green. To drive LED 8 Yellow DDB 690 and DDB 691 must be active at the same time
1076	FnKey LED1 ConR	PSL	Assignment of signal to drive output Function Key LED 1 Red. This LED is associated with Function Key 1
1077	FnKey LED1 ConG	PSL	Assignment of signal to drive output Function Key LED 1 Green. This LED is associated with Function Key 1. To drive function key LED, yellow DDB 692 and DDB 693 must be active at the same time
1094	FnKey LED10 ConR	PSL	Assignment of signal to drive output Function Key LED 10 Red. This LED is associated with Function Key 10
1095	FnKey LED10 ConG	PSL	Assignment of signal to drive output Function Key LED 10 Green. This LED is associated with Function Key 10. To drive function key LED1 yellow, DDB 710 and DDB 711 must be active at the same time
1096	Function Key 1	Function Key	Function Key 1 is activated. In ‘Normal’ mode it is high on keypress and in ‘Toggle’ mode remains high/low on single keypress
1105	Function Key 10	Function Key	Function Key 10 is activated. In ‘Normal’ mode it is high on keypress and in ‘Toggle’ mode remains high/low on single keypress
1106	I^ Maint. Alarm (CB1)	CB Monitoring	Broken Current Maintenance Alarm - circuit breaker cumulative duty alarm set-point
1107	I^ Lockout Alarm (CB1)	CB Monitoring	Broken Current Lockout Alarm - circuit breaker cumulative duty has been exceeded
1108	CB OPs Maint. (CB1)	CB Monitoring	No of Circuit Breaker Operations Maintenance Alarm - indicated due to circuit breaker trip operations threshold
1109	CB OPs Lockout (CB1)	CB Monitoring	No of Circuit Breaker Operations Maintenance Lockout - excessive number of circuit breaker trip operations, safety lockout
1110	CB Op Time Maint (CB1)	CB Monitoring	Excessive Circuit Breaker Operating Time Maintenance Alarm - excessive operation time alarm for the circuit breaker (slow interruption time)
1111	CB Op Time Lockout (CB1)	CB Monitoring	Excessive Circuit Breaker Operating Time Lockout Alarm - excessive operation time alarm for the circuit breaker (too slow interruption)
1112	Fault Freq. Lock (CB1)	CB Monitoring	Excessive fault frequency Lockout Alarm
1113	CB2 I^ Maint	CB2 Monitoring	Broken current maintenance alarm - circuit breaker cumulative duty alarm set-point CB2
1114	CB2 I^ Lockout	CB2 Monitoring	Broken current lockout alarm - circuit breaker cumulative duty has been exceeded CB2
1115	No.CB2 OPs Maint	CB2 Monitoring	No of circuit breaker operations maintenance alarm - indicated due to circuit breaker trip operations threshold CB2
1116	No.CB2 OPs Lock	CB2 Monitoring	No of circuit breaker operations maintenance lockout - excessive number of circuit breaker trip operations, safety lockout CB2
1117	CB2 Time Maint	CB2 Monitoring	Excessive circuit breaker operating time maintenance alarm - excessive operation time alarm for the circuit breaker (slow interruption time) CB2
1118	CB2 Time Lockout	CB2 Monitoring	Excessive circuit breaker operating time lockout alarm - excessive operation time alarm for the circuit breaker (too slow interruption) CB2
1119	CB2FaultFreqLock	CB2 Monitoring	Excessive fault frequency lockout alarm CB2
1120 to 1122	Not used		

DDB No.	English Text	Source	Description
1123	Ch1 Mux Clk	Fiber Monitor Bits	This is an alarm that appears if the channel 1 baud rate is outside the limits 52Kbis/s or 70 Kbits/s
1124	Ch1 Signal Lost	Fiber Monitor Bits	Mux indicates signal lost over channel 1
1125	Ch1 Path Yellow	Fiber Monitor Bits	One way communication. Local relay that is sending over Ch1 indicates that remote end is not receiving
1126	Ch1 Mismatch RxN	Fiber Monitor Bits	Indication of mismatch between Ch1 N*64kbits/s setting and Mux
1127	Ch1 Timeout	Fiber Monitor Bits	Indication that no valid message is received over channel 1 during ‘Channel Timeout’ window
1128	Ch1 Degraded	Fiber Monitor Bits	Indicates poor channel 1 quality
1129	Ch1 Passthrough	Fiber Monitor Bits	Ch1 data received via Ch 2 in 3 ended configuration - self healing indication-
1130 to 1132	Not used		
1133	Ch2 Mux Clk	Fiber Monitor Bits	This is an alarm that appears if the channel 2 baud rate is outside the limits 52Kbis/s or 70 Kbits/s
1134	Ch2 Signal Lost	Fiber Monitor Bits	Mux indicates signal lost over channel 2
1135	Ch2 Path Yellow	Fiber Monitor Bits	One way communication. Local relay that is sending over Ch2 indicates that remote end is not receiving
1136	Ch2 Mismatch RxN	Fiber Monitor Bits	Indication of mismatch between InterMiCOM Ch 2 setting and Mux
1137	Ch2 Timeout	Fiber Monitor Bits	Indication that no valid message is received over channel 2 during ‘Channel Timeout’ window
1138	Ch2 Degraded	Fiber Monitor Bits	Indicates poor channel 2 quality
1139	Ch2 Passthrough	Fiber Monitor Bits	Ch2 data received via Ch 1 in 3 ended configuration - self healing indication
1140 to 1148	Not used/Reserved		
1149	F<1 Timer Block	PSL	Block Underfrequency Stage 1 Timer
1150	F<2 Timer Block	PSL	Block Underfrequency Stage 2 Timer
1151	F<3 Timer Block	PSL	Block Underfrequency Stage 3 Timer
1152	F<4 Timer Block	PSL	Block Underfrequency Stage 4 Timer
1153	F>1 Timer Block	PSL	Block Overfrequency Stage 1 Timer
1154	F>2 Timer Block	PSL	Block Overfrequency Stage 2 Timer
1155	F<1 Start	Frequency Protection	Underfrequency Stage 1 Start
1156	F<2 Start	Frequency Protection	Underfrequency Stage 2 Start
1157	F<3 Start	Frequency Protection	Underfrequency Stage 3 Start
1158	F<4 Start	Frequency Protection	Underfrequency Stage 4 Start
1159	F>1 Start	Frequency Protection	Overfrequency Stage 1 Start
1160	F>2 Start	Frequency Protection	Overfrequency Stage 2 Start

DDB No.	English Text	Source	Description
1161	F<1 Trip	Frequency Protection	Underfrequency Stage 1 Trip
1162	F<2 Trip	Frequency Protection	Underfrequency Stage 2 Trip
1163	F<3 Trip	Frequency Protection	Underfrequency Stage 3 Trip
1164	F<4 Trip	Frequency Protection	Underfrequency Stage 4 Trip
1165	F>1 Trip	Frequency Protection	Overfrequency Stage 1 Trip
1166	F>2 Trip	Frequency Protection	Overfrequency Stage 2 Trip
1167	Inhibit F<1	PSL	Inhibit stage 1 Under frequency protection
1168	Inhibit F<2	PSL	Inhibit stage 2 Underfrequency protection
1169	Inhibit F<3	PSL	Inhibit stage 3 Underfrequency protection
1170	Inhibit F<4	PSL	Inhibit stage 4 Underfrequency protection
1171	Inhibit F>1	PSL	Inhibit stage 1 Overfrequency protection
1172	Inhibit F>2	PSL	Inhibit stage 2 Overfrequency protection
1173 to 1175	Not used		
1176	HMI Access Lvl 1		It indicates that level access 1 for HMI interface is enabled
1177	HMI Access Lvl 2		It indicates that level access 2 for HMI interface is enabled
1178	FPort AccessLvl1		It indicates that level access 1 for the front port interface is enabled
1179	FPort AccessLvl2		It indicates that level access 2 for the front port interface is enabled
1180	RPrt1 AccessLvl1		It indicates that level access 1 for the rear port 1 interface is enabled
1181	RPrt1 AccessLvl2		It indicates that level access 2 for the rear port 1 interface is enabled
1182	RPrt2 AccessLvl1		It indicates that level access 1 for the rear port 2 interface is enabled
1183	RPrt2 AccessLvl2		It indicates that level access 2 for the rear port 2 interface is enabled
1184	Monitor Bit 1	Commissioning Test	Monitor Port signal 1 - allows mapped monitor signals to be mapped to disturbance recorder or contacts
1191	Monitor Bit 8	Commissioning Test	Monitor Port signal 8
1192	Reserved		
1193	Not used		
1194	PSL Int 1	PSL	PSL Internal Node
1293	PSL Int 100	PSL	PSL Internal Node
1294	VTS Ia>	VT Supervision	“VTS I> Inhibit” setting has been exceeded in phase a
1295	VTS Ib>	VT Supervision	“VTS I> Inhibit” setting has been exceeded in phase b
1296	VTS Ic>	VT Supervision	“VTS I> Inhibit” setting has been exceeded in phase c
1297	VTS Va>	VT Supervision	Va has exceed 30 volts (drop off at 10 volts)
1298	VTS Vb>	VT Supervision	Vb has exceed 30 volts (drop off at 10 volts)
1299	VTS Vc>	VT Supervision	Vc has exceed 30 volts (drop off at 10 volts)
1300	VTS I2>	VT Supervision	“VTS I2> Inhibit” setting has been exceeded
1301	VTS V2>	VT Supervision	V2 has exceed 10 volts
1302	VTS Ia delta>	VT Supervision	Superimposed phase a current has exceed 0.1In
1303	VTS Ib delta>	VT Supervision	Superimposed phase b current has exceed 0.1In

DDB No.	English Text	Source	Description
1304	VTS Ic delta>	VT Supervision	Superimposed phase c current has exceed 0.1In
1305 to 1374	Reserved		
1375	Teleprotection Disturbed		This is an output signal available in the PSL, that could be mapped to “Carrier failure” for IEC870-5-103.
1376	I>> Back Up Supervision		This signal is ON if an overcurrent stage is selected to be enabled on VTS and distance is blocked by VTS
1377	O/C Trip By VTS		This signal is ON if DDB 1376 is ON and one of the overcurrent stages set to be enabled on VTS condition trips
1378	Teleprot Tx		This is an output signal available in the PSL, which could be mapped to a signal send of one of the two teleprotection channels
1379	Teleprot Rx		This is an output signal available in the PSL, which could be mapped to a signal receive of one of the two teleprotection channels
1380	Group Warning		This is an output signal available in the PSL, which can be mapped in IEC870-5-103 to a minor defect which does not shut down the main protection
1381	Group Alarm		This is an output signal available in the PSL, which can be mapped in IEC870-5-103 to a major problem normally linked to the watchdog
1382	AR On Pulse		This is an output signal available in the PSL, which can be mapped to enable AR via pulse
1383	AR OFF Pulse		This is an output signal available in the PSL, which can be mapped to disable AR via pulse
1384	AR Enable		This is an output signal available in the PSL, which can be mapped to enable AR
1385	AR In Service		Auto-reclose in service
1386	MaxCh1 PropDelay		Setting MaxCh 1 PropDelay has been exceeded
1387	MaxCh2 PropDelay		Setting MaxCh 2 PropDelay has been exceeded
1388 to 1403	Reserved		
1404	VTS Blk Distance	VTS Logic	Signal from the VTS logic that can be used to block operation of the distance elements
1405 to 1407	Not used		
1408	CB2 Lead	Auto-reclose	If setting "Leader Select By:" = Opto, then preferred leader CB is CB1 if input DDB "CB2 LEAD" is low, or CB2 if DDB "CB2 LEAD" is high P446 Only
1409	Follower AR 1P	Auto-reclose	If setting "Foll AR Mode" = Opto, then if input DDB "FARSP" is high, the follower CB is enabled for single phase auto-reclose, if "FARSP" is low, the follower CB is NOT enabled for single phase auto-reclose P446 Only
1410	Follower AR 3P	Auto-reclose	If setting "Foll AR Mode" = Opto, then if input DDB "FAR3P" is high, the follower CB is enabled for three phase auto-reclose, if "FAR3P" is low, the follower CB is NOT enabled for three phase auto-reclose P446 Only
1411	CB2 AR 3p InProg	Auto-reclose	Auto-reclose in progress CB2 P446 Only
1412 to 1416	Not used		
1417	Ext Rst CB2 AROK	PSL	DDB mapped in PSL from opto or comms input. This input DDB is used when required to reset any CB2 Successful Auto-reclose" signal P446 Only

DDB No.	English Text	Source	Description
1418	Ext Rst CB2Shots	PSL	DDB mapped in PSL from opto or comms input. This input DDB is used when required to reset the CB2 cumulative "Shots" counters P446 Only
1419	Rst CB2 CloseDly	PSL	DDB mapped in PSL. Reset Manual CB2 Close Timer Delay (stop & reset Manual Close Delay time for closing CB2) P446 Only
1420	Inhibit AR	PSL	External signal to block auto-reclose and reset any auto-reclose cycle in progress P446 Only
1421	Block CB2 AR	PSL	DDB mapped in PSL from opto or comms input. External signal to force CB2 auto-reclose to lockout P446 Only
1422	Rst CB2 Lockout	PSL	DDB mapped in PSL from opto or comms input. Reset Lockout Opto Input to reset CB2 Lockout state P446 Only
1423	MCB/VTS CB2 CS	PSL	DDB mapped in PSL from opto input (Bus2 VT secondary MCB tripped or VT fail detected by external VTS scheme), or signal from host relay VTS scheme P446 Only
1424	Inhibit LB2	PSL	DDB mapped in PSL from opto input (external signal to inhibit Live Bus 2 function) P446 Only
1425	Inhibit DB2	PSL	DDB mapped in PSL from opto input (external signal to inhibit Dead Bus 2 function) P446 Only
1426	CB2 CS1 Enabled	PSL	DDB mapped in PSL from opto input or logic DDBs (enable CS2-1 check synchronism function) P446 Only
1427	CB2 CS2 Enabled	PSL	DDB mapped in PSL from opto input or logic DDBs (enable CS2-2 check synchronism function) P446 Only
1428	CB2 In Service		Signal from CB In Service logic, indicating that CB2 is "In Service", i.e. can be initiated to auto-reclose P446 Only
1429	CB2 NoAR	Auto-reclose	CB2 not available for auto-reclose P446 Only
1430	Not used		
1431	Leader CB2	Auto-reclose	CB2 set as leader P446 Only
1432	Follower CB1	Auto-reclose	CB1 set as follower P446 Only
1433	Follower CB2	Auto-reclose	CB2 set as follower P446 Only
1434	CB2 AR Init	Auto-reclose	Indicates initiation of a CB2 auto-reclose cycle P446 Only
1435	CB2 ARIP	Auto-reclose	CB2 auto-reclose cycle in progress P446 Only
1436	Not used		
1437	Test Trip CB2A		Trip CB2 A Ph for test trip & AR P446 Only
1438	Test Trip CB2B		Trip CB2 B Ph for test trip & AR P446 Only

DDB No.	English Text	Source	Description
1439	Test Trip CB2C		Trip CB2 C Ph for test trip & AR P446 Only
1440	Not used		
1441	CB2 Failed AR		CB2 auto-reclose failed due to persistent fault P446 Only
1442	DTOK CB2L 1P		Output DDB indicates conditions to enable CB2 lead single phase auto-reclose dead time to run are satisfied P446 Only
1443	DTOK CB2L 3P		Output DDB indicates conditions to enable CB2 lead three phase auto-reclose dead time to run are satisfied P446 Only
1444	CB2 3P DTime		Indicates CB2 three phase auto-reclose dead time running P446 Only
1445	En CB2 Follower		Indicates conditions are satisfied to enable CB2 follower sequence P446 Only
1446	1P Follower Time		Indicates a single pole auto-reclose follower time is running (either CB) P446 Only
1447	3P Follower Time		Indicates a three pole auto-reclose follower time is running (either CB) P446 Only
1448	Auto Close CB2		Signal from auto-reclose logic to initiate CB2 close via “CB2 CB Control” P446 Only
1449	Set CB2 Close		Indicates a CB2 Auto Close signal has been issued P446 Only
1450	CB2 Control		Output DDB can be applied to inhibit CB2 reclose by adjacent scheme until local auto-reclose scheme confirms it is OK to close CB2 P446 Only
1451	CB2 Succ 1P AR		CB2 successful single phase AR P446 Only
1452	CB2 Succ 3P AR		CB2 successful three phase AR P446 Only
1453	CB2 Close inProg		CB2 Manual Close initiated - awaiting Man Close Delay time P446 Only
1454	CB2 Fast SCOK		OK to reclose CB2 with sync check without waiting for dead time to complete P446 Only
1455	CB2L SCOK		System conditions OK to reclose CB2 as leader when dead time complete P446 Only
1456	CB2F SCOK		System conditions OK to reclose CB2 when follower time complete P446 Only
1457	Not used		
1458	CB2 Man SCOK		System conditions OK to manually close CB2 P446 Only
1459	CB2 Fail Pr Trip		signal to force CB2 AR lockout if CB2 fails to trip when protection operates P446 Only
1460	Not used		
1461	Live Bus 2		Indicates Bus 2 input is live, i.e. voltage >= setting "Live Bus 2" P446 Only
1462	Dead Bus 2		Indicates Bus 2 input is dead i.e. voltage < setting "Dead Bus 2" P446 Only

DDB No.	English Text	Source	Description
1463	CB2 CS2 OK		CB2 close with synchronism check type 2 is permitted (setting CS2-2 = Enabled), and Line and Bus 2 voltages satisfy relay settings for CB2 synchronism check type 2 P446 Only
1464	CB1 CS2 SlipF>		Line-Bus 1 slip freq > SlipFr 1-2 setting (frequency difference (slip) between line voltage and bus 1 voltage is greater than maximum slip permitted for CB1 synchronism check type 2)
1465	CB1 CS2 SlipF<		Line-Bus 1 slip freq < SlipFr 1-2 setting (frequency difference (slip) between line voltage and bus 1 voltage is within the permitted range for CB1 synchronism check type 2)
1466	CB2 CS1 SlipF>		Line-Bus 2 slip freq > SlipFr 2-1 setting (frequency difference (slip) between line voltage and bus 2 voltage is greater than maximum slip permitted for CB2 synchronism check type 1) P446 Only
1467	CB2 CS1 SlipF<		Line-Bus 2 slip freq < SlipFr 2-1 setting (frequency difference (slip) between line voltage and bus 2 voltage is within the permitted range for CB2 synchronism check type 1) P446 Only
1468	CB2 CS2 SlipF>		Line-Bus 2 slip freq > SlipFr 2-2 setting (frequency difference (slip) between line voltage and bus 2 voltage is greater than maximum slip permitted for CB2 synchronism check type 2) P446 Only
1469	CB2 CS2 SlipF<		Line-Bus 2 slip freq < SlipFr 2-2 setting (frequency difference (slip) between line voltage and bus 2 voltage is within the permitted range for CB2 synchronism check type 2) P446 Only
1470	CB2 CS1 VL>VB		Voltage magnitude difference between Line V and Bus2 V is greater than setting "VDiff2-1" (line V > Bus V) P446 Only
1471	CB2 CS2 VL>VB		Voltage magnitude difference between Line V and Bus2 V is greater than setting "VDiff2-1" (line V > Bus V) P446 Only
1472	CB2 CS1 VL<VB		Voltage magnitude difference between Line V and Bus2 V is greater than setting "VDiff2-1" (line V < Bus V) P446 Only
1473	CB2 CS2 VL<VB		Voltage magnitude difference between Line V and Bus2 V is greater than setting "VDiff2-1" (line V < Bus V) P446 Only
1474	CB2 CS1 FL>FB		Frequency difference between Line V and Bus2 V is greater than setting "SlipFr2-1" (line freq > Bus freq) P446 Only
1475	CB2 CS2 FL>FB		Frequency difference between Line V and Bus2 V is greater than setting "SlipFr2-2" (line freq > Bus freq) P446 Only
1476	CB2 CS1 FL<FB		Frequency difference between Line V and Bus2 V is greater than setting "SlipFr2-1" (line freq < Bus freq) P446 Only
1477	CB2 CS2 FL<FB		Frequency difference between Line V and Bus2 V is greater than setting "SlipFr2-2" (line freq < Bus freq) P446 Only
1478	CB2 CS1 AngHigh+		Line/Bus2 phase angle in range: +Angle 2-1 to +180deg (anticlockwise from Vbus) P446 Only

DDB No.	English Text	Source	Description
1479	CB2 CS1 AngHigh-		Line/Bus2 phase angle in range: -Angle 2-1 to -180deg (clockwise from Vbus) P446 Only
1480	CB2 CS2 AngHigh+		Line/Bus2 phase angle in range: +Angle 2-2 to +180deg (anticlockwise from Vbus) P446 Only
1481	CB2 CS2 AngHigh-		Line/Bus2 phase angle in range: -Angle 2-2 to -180deg (clockwise from Vbus) P446 Only
1482	CB2 CS AngRotACW		Line freq > (Bus2 freq + 0.001Hz) (Line voltage vector rotating anticlockwise relative to VBus2) P446 Only
1483	CB2 CS AngRotCW		Bus2 freq > (Line freq + 0.001Hz) (Line voltage vector rotating clockwise relative to VBus2) P446 Only
1484	SChksInactiveCB2		Output from CB2 system check logic: indicates system checks for CB2 are disabled (setting "System Checks CB2" = Disabled or global setting "System Checks" = Disabled) P446 Only
1485	AR Force CB2 3P	Auto-reclose	This DDB is set when the auto-reclose logic has determined that single pole tripping/auto-reclosing is not permitted for CB2. It can be applied in PSL when required to force trip conversion logic for internal and/or external protection to three phase trip mode for CB2 P446 Only
1486	Not used		
1487	Not used		
1488	En CB1 Follower		Indicates conditions are satisfied to enable CB1 follower sequence P446 Only
1489 to 1490	Not used		
1491	Not used		
1492	Not used		
1493	CB1 CS2 FL>FB		Frequency difference between Line V and Bus1 V is greater than setting "SlipFr1-2" (line freq > Bus freq)
1494	CB1 CS2 FL<FB		Frequency difference between Line V and Bus1 V is greater than setting "SlipFr1-2" (line freq < Bus freq)
1495	CB1 CS2 AngHigh+		Line/Bus1 phase angle in range: +Angle 1-2 to +180deg (anticlockwise from Vbus)
1496	CB1 CS2 AngHigh-		Line/Bus1 phase angle in range: -Angle 1-2 to -180deg (clockwise from Vbus)
1497	Lead AR 1P	PSL	If setting "Lead AR Mode" = Opto, then if input DDB "LARSP" is high, the leader CB is enabled for single phase auto-reclose, if "LARSP" is low, the leader CB is NOT enabled for single phase auto-reclose P446 Only
1498	Lead AR 3P	PSL	If setting "Lead AR Mode" = Opto, then if input DDB "LAR3P" is high, the leader CB is enabled for three phase auto-reclose, if "LAR3P" is low, the leader CB is NOT enabled for three phase auto-reclose P446 Only
1499	CB2 Trip AR MemA		CB2 A Ph trip & AR initiation memory P446 Only
1500	CB2 Trip AR MemB		CB2 B Ph trip & AR initiation memory P446 Only

DDB No.	English Text	Source	Description
1501	CB2 Trip AR MemC		CB2 C Ph trip & AR initiation memory P446 Only
1502 to 1503	Not used		
1504	Init APh AR Test	PSL	DDB mapped in PSL from opto or comms input. Input high-low operation will initiate APh test trip & auto-reclose cycle
1505	Init BPh AR Test	PSL	DDB mapped in PSL from opto or comms input. Input high-low operation will initiate BPh test trip & auto-reclose cycle
1506	Init CPh AR Test	PSL	DDB mapped in PSL from opto or comms input. Input high-low operation will initiate CPh test trip & auto-reclose cycle
1507	Init 3P AR Test	PSL	DDB mapped in PSL from opto or comms input. Input high-low operation will initiate 3Ph test trip & auto-reclose cycle
1508	Ext Fault APh	PSL	DDB mapped in PSL from opto or comms input: indicates external protection operated for fault involving A phase
1509	Ext Fault BPh	PSL	DDB mapped in PSL from opto or comms input: indicates external protection operated for fault involving B phase
1510	Ext Fault CPh	PSL	DDB mapped in PSL from opto or comms input: indicates external protection operated for fault involving C phase
1511 to 1516	Not used		
1517	Ext Rst CB1 AROK	PSL	DDB mapped in PSL from opto or comms input. This input DDB is used when required to reset any CB1 "Successful Auto-reclose" signal
1518	Ext Rst CB1Shots	PSL	DDB mapped in PSL from opto or comms input. This input DDB is used when required to reset the CB1 cumulative "Shots" counters
1519 to 1520	Not used		
1521	MCB/VTS CB1 CS	PSL	DDB mapped in PSL from opto input (Bus1 VT secondary MCB tripped or VT fail detected by external VTS scheme), or signal from host relay VTS scheme
1522	Inhibit LL	PSL	DDB mapped in PSL from opto input (external signal to inhibit Live Line function)
1523	Inhibit DL	PSL	DDB mapped in PSL from opto input (external signal to inhibit Dead Line function)
1524	Inhibit LB1	PSL	DDB mapped in PSL from opto input (external signal to inhibit Live Bus 1 function)
1525	Inhibit DB1	PSL	DDB mapped in PSL from opto input (external signal to inhibit Dead Bus 1 function)
1526	CB1 In Service		CB1 In Service (can be initiated for auto-reclose)
1527	Not used		
1528	CB1 NoAR	Auto-reclose	CB1 not available for auto-reclose
1529	Not used		
1530	Leader CB1	Auto-reclose	CB1 set as leader P446 Only
1531 to 1534	Not used		
1535	CB1 Trip AR MemA		A Ph trip & AR initiation memory
1536	CB1 Trip AR MemB		B Ph trip & AR initiation memory

DDB No.	English Text	Source	Description
1537	CB1 Trip AR MemC		C Ph trip & AR initiation memory
1538 to 1540	Not used		
1541	AR Start	Auto-reclose	Any AR initiation signal present
1542	ARIP	Auto-reclose	Any AR cycle in progress
1543	CB1 AR Init	Auto-reclose	CB1 AR cycle initiation
1544	CB1 ARIP	Auto-reclose	CB1 AR cycle in progress
1545	Not used		
1546	SC Count>Shots		Sequence counts greater than shots
1547	Evolve 3Ph		Convert SPAR to 3PAR. DDB mapped to give 100ms pulse to CB1 Trip 3Ph and CB2 Trip 3Ph outputs
1548 to 1549	Not used		
1550	CB1 Failed AR		CB1 AR failed due to persistent fault
1551	DTOK All		Enabling condition for any dead time
1552	DTOK CB1L 1P		required for CB1 lead SPAR D Time
1553	DTOK CB1L 3P		required for CB1 lead 3PAR D Time
1554	1P DTime		Single pole dead time in progress
1555	OK Time 3P		OK to start 3PAR dead time
1556	3P DTime1		3Phase dead time 1 running
1557	3P DTime2		3Phase dead time 2 running
1558	3P DTime3		3Phase dead time 3 running
1559	3P DTime4		3Phase dead time 4 running
1560	CB1 3P DTime		CB1 3PAR dead time running
1561	1PF TComp		Either CB SP follower time complete P446 Only
1562	3PF TComp		Either CB 3P follower time complete P446 Only
1563 to 1564	Not used		
1565	Set CB1 Close		DDB (Optional PSL mapping to indication)
1566	CB1 Control		Inhibits CB1 reclose by adjacent scheme
1567	1P Reclaim Time		Single Ph AR reclaim time running
1568	1P Reclaim TComp		Single Ph AR reclaim time complete
1569	3P Reclaim Time		Three Ph AR reclaim time running
1570	3P Reclaim TComp		Three Ph AR reclaim time complete
1571	CB1 Succ 1P AR		CB1 successful single phase AR
1572	CB1 Fast SCOK		OK to reclose CB1 with sync check without waiting for dead time to complete
1573	CB1L SCOK		System conditions OK to reclose CB1 when dead time complete
1574	CB1 Man SCOK		System conditions OK to manually close CB1
1575	CB1 Fail Pr Trip		signal to force CB1 AR lockout
1576	Not used		
1577	CB2 CS1 OK		CS2-1 is enabled and Line and Bus 2 voltages meet CS2-1 settings P446 Only
1578	CB1 CS1 SlipF>		Line-Bus 1 slip freq > SlipFr 1-1 setting

DDB No.	English Text	Source	Description
1579	CB1 CS1 SlipF<		Line-Bus 1 slip freq < SlipFr 1-1 setting
1580	CS VLine<		Line Volts < CS UV setting
1581	CS VLine>		Line Volts > CS OV setting
1582	CS VBus1<		Bus1 Volts < CS UV setting
1583	CS VBus1>		Bus1 Volts > CS OV setting
1584	CS VBus2<		Bus2 Volts < CS UV setting P446 Only
1585	CS VBus2>		Bus2 Volts > CS OV setting P446 Only
1586	CB1 CS1 VL>VB		Line V > (Bus1 V + [VDiff1-1])
1587	CB1 CS2 VL>VB		Line V > (Bus1 V + [VDiff1-2])
1588	CB1 CS1 VL<VB		Bus1 V > (Line V + [VDiff1-1])
1589	CB1 CS2 VL<VB		Bus1 V > (Line V + [VDiff1-2])
1590	CB1 CS1 FL>FB		Line F > (Bus1 F + [SlipFr1-1])
1591	CB1 CS1 FL<FB		Bus1 F > (Line F + [SlipFr1-1])
1592	CB1 CS1 AngHigh+		Line/Bus1 phase angle in range: +Angle 1-1 to +180deg
1593	CB1 CS1 AngHigh-		Line/Bus1 phase angle in range: -Angle 1-1 to -180deg
1594	CB1 CS AngRotACW		Line freq > (Bus1 freq + 0.001Hz) (CS1 Angle Rotating Anticlockwise)
1595	CB1 CS AngRotCW		Bus1 freq > (Line freq + 0.001Hz) (CS1 Angle Rotating Clockwise)
1596	Not used		
1597	Rst CB2 Data		Rst CB2 All Val P446 Only
1598	Not used		
1599	CB2 LO Alarm		CB2 LO Alarm P446 Only
1600	CB2 Trip 3ph	Trip Conversion Logic	3 Phase Trip 2 P446 Only
1601	CB2 Trip OutputA	Trip Conversion Logic	A Phase Trip 2 P446 Only
1602	CB2 Trip OutputB	Trip Conversion Logic	B Phase Trip 2 P446 Only
1603	CB2 Trip OutputC	Trip Conversion Logic	C Phase Trip 2 P446 Only
1604	Force 3PTrip CB2	PSL	External input via DDB to force host relay trip conversion logic to issue a three phase trip signal to CB2 for all faults P446 Only
1605	Enable AR CB2		External input via DDB to enable CB2, if "in service", to be initiated for auto-reclosing by an AR initiation signal from protection. DDB input defaults to high if not mapped in PSL, so CB2 AR initiation is permitted P446 Only
1606	Pole Discrep.CB2	PSL	Pole Discrepancy P446 Only
1607	Pole Discrep.CB2	Pole discrepency	Pole Discrepancy P446 Only
1608	CB2 Trip I/P 3Ph	PSL	Trip 3 Phase - Input to Trip Latching Logic P446 Only

DDB No.	English Text	Source	Description
1609	Enable AR CB1	PSL	External input via DDB mapped in PSL to enable CB1, if "in service", to be initiated for auto-reclosing by an AR initiation signal from protection. DDB input defaults to high if not mapped in PSL, so CB1 AR initiation is permitted
1610 to 1615	Not used		
1616	PSL Int 101	PSL	PSL internal node
1665	PSL Int 150	PSL	PSL internal node
1666 to 1695	Not used		
1696	IEC Usr 01 Open	PSL	IEC61850 User Dual Point Status 1 Open
1697	IEC Usr 01 Close	PSL	IEC61850 User Dual Point Status 1 Close
1710	IEC Usr 08 Open	PSL	IEC61850 User Dual Point Status 8 Open
1711	IEC Usr 08 Close	PSL	IEC61850 User Dual Point Status 8 Close
1712 to 1727	Not Used		
1728	Quality VIP 1		GOOSE virtual input 1 - provides the Quality attributes of any data object in an incoming GOOSE message
1759	Quality VIP 32		GOOSE virtual input 32 - provides the Quality attributes of any data object in an incoming GOOSE message
1760	PubPres VIP 1		GOOSE virtual input 1- indicates if the GOOSE publisher responsible for publishing the data that derives a virtual input is present.
1791	PubPres VIP 32		GOOSE virtual input 32- indicates if the GOOSE publisher responsible for publishing the data that derives a virtual input is present.

Table 2 - DDB Numbers

2.1 Factory Default Programmable Scheme Logic (PSL)

The following section details the default settings of the PSL.

The P443 model options are as follows:

Model	Opto Inputs	Relay Outputs
P443xxxAxxxxxxK	16	24 standard
P443xxxBxxxxxxK	24	32 standard
P443xxxCxxxxxxK	16	16 standard and 4 high break
P443xxxDxxxxxxK	24	16 standard and 8 high break
P443xxxYxxxxxxK	32	32 standard

Table 3 - P443 model options

The P446 model options are as follows:

Model	Opto Inputs	Relay Outputs
P446xxxBxxxxxxK	24	32 standard
P446xxxCxxxxxxK	24	8 standard and 12 high break
P446xxxDxxxxxxK	24	16 standard and 8 high break

Table 4 - P446 model options

2.2 Logic Input Mappings

The default mappings for each of the opto-isolated inputs are as shown in:

- Table 5 - Default mappings for P443 (A & C)
- Table 6 - Default mappings for P443 (B & D)
- Table 7 - Default mappings for P446

Opto-Input No	P443 Options A & C Relay Text	Function
1	Input L1	L1 Not Used
2	Input L2	L2 Not Used
3	Input L3	L3 Aid 1 Receive
4	Input L4	L4 Aid 1 COS/LGS
5	Input L5	L5 Reset LEDs
6	Input L6	L6 Ext Trip A
7	Input L7	L7 Ext Trip B
8	Input L8	L8 Ext Trip C
9	Input L9	L9 CB AuxA 52-B
10	Input L10	L10 CB AuxB 52-B
11	Input L11	L11 CB AuxC 52-B
12	Input L12	L12 MCB/VTS
13	Input L13	L13 CB Close Man
14	Input L14	L14 Reset Lckout
15	Input L15	L15 CB Healthy

Opto-Input No	P443 Options A & C Relay Text	Function
16	Input L16	L16 BAR

Table 5 - Default mappings for P443 (A & C)

Opto-Input No	P443 Options B & D Relay Text	Function
1	Input L1	L1 Not Used
2	Input L2	L2 Not Used
3	Input L3	L3 Aid 1 Receive
4	Input L4	L4 Aid 1 COS/LGS
5	Input L5	L5 Reset LEDs
6	Input L6	L6 Ext Trip A
7	Input L7	L7 Ext Trip B
8	Input L8	L8 Ext Trip C
9	Input L9	L9 CB AuxA 52-B
10	Input L10	L10 CB AuxB 52-B
11	Input L11	L11 CB AuxC 52-B
12	Input L12	L12 MCB/VTS
13	Input L13	L13 CB Close Man
14	Input L14	L14 Reset Lckout
15	Input L15	L15 CB Healthy
16	Input L16	L16 BAR
17	Input L17	L17 Not Used
18	Input L18	L18 Not Used
19	Input L19	L19 IM64 1
20	Input L20	L20 IM64 2
21	Input L21	L21 IM64 3
22	Input L22	L22 IM64 4
23	Input L23	L23 Not Used
24	Input L24	L24 Not Used

Table 6 - Default mappings for P443 (B & D)

Opto-Input No	P446 Relay Text	Function
1	Input L1	L1 Not Used
2	Input L2	L2 BAR
3	Input L3	L3 Aid 1 Receive
4	Input L4	L4 Aid 1 COS/LGS
5	Input L5	L5 Reset LEDs
6	Input L6	L6 CB2 AuxA 52-B
7	Input L7	L7 CB2 AuxB 52-B
8	Input L8	L8 CB2 AuxC 52-B
9	Input L9	L9 CB1 AuxA 52-B
10	Input L10	L10 CB1 AuxB 52-B
11	Input L11	L11 CB1 AuxC 52-B
12	Input L12	L12 MCB/VTS

Opto-Input No	P446 Relay Text	Function
13	Input L13	L13 CB1 CloseMan
14	Input L14	L14 CB2 CloseMan
15	Input L15	L15 CB1 Healthy
16	Input L16	L16 Reset Lckout
17	Input L17	L17 CB2 Healthy
18	Input L18	L18 IM64 1
19	Input L19	L19 CB1 Ext Trip A
20	Input L20	L20 CB1 Ext Trip B
21	Input L21	L21 CB1 Ext Trip C
22	Input L22	L22 CB2 Ext Trip A
23	Input L23	L23 CB2 Ext Trip B
24	Input L24	L24 CB2 Ext Trip C

Table 7 - Default mappings for P446

2.3 Standard Relay Output Contact Mappings

The default mappings for each of the relay output contacts are as shown in the following table:

Relay Contact No	P443 Option A Relay Text	P443 Option A Relay Conditioner	Function
1	Output R1	Straight-through	R1 Trip Z1
2	Output R2	Straight-through	R2 Any Start
3	Output R3	Dwell 100ms	R3 Any Trip
4	Output R4	Dwell 500ms	R4 General Alarm
5	Output R5	Straight-through	R5 IM64 1
6	Output R6	Dwell 100ms	R6 CB Fail Time1
7	Output R7	Straight-through	R7 Cntl CB Close
8	Output R8	Straight-through	R8 Cntl CB Trip
9	Output R9	Dwell 100ms	R9 Trip A
10	Output R10	Dwell 100ms	R10 Trip B
11	Output R11	Dwell 100ms	R11 Trip C
12	Output R12	Straight-through	R12 AR in Prog
13	Output R13	Straight-through	R13 SuccessClose
14	Output R14	Straight-through	R14 AR Lockout
15	Output R15	Straight-through	R15 AR InService
16	Output R16	Straight-through	R16 BAR
17	Output R17	Dwell 100ms	R17 Trip A
18	Output R18	Dwell 100ms	R18 Trip B
19	Output R19	Dwell 100ms	R19 Trip C
20	Output R20	Straight-through	R20 DistInst Trp
21	Output R21	Straight-through	R21 Dist Dly Trp
22	Output R22	Straight-through	R22 Aid DEF Trip
23	Output R23	Straight-through	R23 Aid Dir Trip
24	Output R24	Straight-through	R24 Aid 1 Send

Table 8 - Default mappings for P443 (A)

Relay Contact No	P443 Option B Relay Text	P443 Option B Relay Conditioner	Function
1	Output R1	Straight-through	R1 Trip Z1
2	Output R2	Straight-through	R2 Any Start
3	Output R3	Dwell 100ms	R3 Any Trip
4	Output R4	Dwell 500ms	R4 General Alarm
5	Output R5	Straight-through	R5 IM64 1
6	Output R6	Dwell 100ms	R6 CB Fail Time1
7	Output R7	Straight-through	R7 Cntl CB Close
8	Output R8	Straight-through	R8 Cntl CB Trip
9	Output R9	Dwell 100ms	R9 Trip A
10	Output R10	Dwell 100ms	R10 Trip B
11	Output R11	Dwell 100ms	R11 Trip C
12	Output R12	Straight-through	R12 AR in Prog
13	Output R13	Straight-through	R13 SuccessClose
14	Output R14	Straight-through	R14 AR Lockout
15	Output R15	Straight-through	R15 AR InService
16	Output R16	Straight-through	R16 BAR
17	Output R17	Dwell 100ms	R17 Trip A
18	Output R18	Dwell 100ms	R18 Trip B
19	Output R19	Dwell 100ms	R19 Trip C
20	Output R20	Straight-through	R20 DistInst Trp
21	Output R21	Straight-through	R21 Dist Dly Trp
22	Output R22	Straight-through	R22 Aid DEF Trip
23	Output R23	Straight-through	R23 Aid Dir Trip
24	Output R24	Straight-through	R24 Aid 1 Send
25	Output R25	Straight-through	R25 Not Used
26	Output R26	Straight-through	R26 Not Used
27	Output R27	Straight-through	R27 VTS
28	Output R28	Straight-through	R28 PSB
29	Output R29	Straight-through	R29 IM64 2
30	Output R30	Straight-through	R30 IM64 3
31	Output R31	Straight-through	R31 IM64 4
32	Output R32	Straight-through	R32 Not Used

Table 9 - Default mappings for P443 (B)

Relay Contact No	P446 Option B Relay Text	P446 Option B Relay Conditioner	Function
1	Output R1	Straight-through	R1 Trip Z1
2	Output R2	Straight-through	R2 Any Start
3	Output R3	Dwell 100ms	R3 Any Trip
4	Output R4	Dwell 500ms	R4 General Alarm
5	Output R5	Straight-through	R5 IM64 1
6	Output R6	Dwell 100ms	R6 CB1 Fail1Trip

Relay Contact No	P446 Option B Relay Text	P446 Option B Relay Conditioner	Function
7	Output R7	Straight-through	R7 Cntl CB1 Close
8	Output R8	Straight-through	R8 Cntl CB1 Trip
9	Output R9	Dwell 100ms	R9 CB1 Trip A
10	Output R10	Dwell 100ms	R10 CB1 Trip B
11	Output R11	Dwell 100ms	R11 CB1 Trip C
12	Output R12	Dwell 100ms	R12 CB2 Fail1Trip
13	Output R13	Straight-through	R13 CntlCB2Close
14	Output R14	Straight-through	R14 Cntl CB2Trip
15	Output R15	Dwell 100ms	R15 CB1 Fail2Trip
16	Output R16	Dwell 100ms	R16 CB2 Fail2Trip
17	Output R17	Dwell 100ms	R17 CB2 Trip A
18	Output R18	Dwell 100ms	R18 CB2 Trip B
19	Output R19	Dwell 100ms	R19 CB2 Trip C
20	Output R20	Straight-through	R20 DistInst Trp
21	Output R21	Straight-through	R21 Dist Dly Trp
22	Output R22	Straight-through	R22 Aid DEF Trip
23	Output R23	Straight-through	R23 SignalingFail
24	Output R24	Straight-through	R24 Aid 1 Send
25	Output R25	Straight-through	R25 Not Used
26	Output R26	Straight-through	R26 Not Used
27	Output R27	Straight-through	R27 VTS
28	Output R28	Straight-through	R28 PSB
29	Output R29	Straight-through	R29 AR CB1 Lockout
30	Output R30	Straight-through	R30 AR CB2 Lockout
31	Output R31	Straight-through	R31 ARIP
32	Output R32	Straight-through	R32 SuccessClose

Note *A fault record can be generated by connecting one or a number of contacts to the "Fault Record Trigger" in PSL. It is recommended that the triggering contact is self reset and not latching. If a latching contact is used, the fault record is not generated until the contact has fully reset.*

Table 10 - Default mappings for P446 (B)

2.4 Optional High Break Relay Output Contact Mappings

The default mappings for each of the standard and high break relay output contacts are as shown in this table:

Relay Contact No	P443 Option C Relay Text	P443 Option C Relay Conditioner	Function	High break contact?
1	Output R1	Straight-through	R1 Trip Z1	No
2	Output R2	Straight-through	R2 Any Start	No
3	Output R3	Dwell 100ms	R3 Any Trip	No
4	Output R4	Dwell 500ms	R4 General Alarm	No
5	Output R5	Straight-through	R5 IM64 1	No

Relay Contact No	P443 Option C Relay Text	P443 Option C Relay Conditioner	Function	High break contact?
6	Output R6	Dwell 100ms	R6 CB Fail Time1	No
7	Output R7	Straight-through	R7 Cntl CB Close	No
8	Output R8	Straight-through	R8 Cntl CB Trip	No
9	Output R9	Dwell 100ms	R9 Trip A	No
10	Output R10	Dwell 100ms	R10 Trip B	No
11	Output R11	Dwell 100ms	R11 Trip C	No
12	Output R12	Straight-through	R12 AR in Prog	No
13	Output R13	Straight-through	R13 SuccessClose	No
14	Output R14	Straight-through	R14 AR Lockout	No
15	Output R15	Straight-through	R15 AR InService	No
16	Output R16	Straight-through	R16 Aid 1 Send	No
17	Output R17	Dwell 100ms	R17 Trip A	Yes
18	Output R18	Dwell 100ms	R18 Trip B	Yes
19	Output R19	Dwell 100ms	R19 Trip C	Yes
20	Output R20	Dwell 100ms	R20 Any Trip	Yes

Table 11 - Default mappings for P443 (C)

Relay Contact No	P443 Option D Relay Text	P443 Option D Relay Conditioner	Function	High break contact?
1	Output R1	Straight-through	R1 Trip Z1	No
2	Output R2	Straight-through	R2 Any Start	No
3	Output R3	Dwell 100ms	R3 Any Trip	No
4	Output R4	Dwell 500ms	R4 General Alarm	No
5	Output R5	Straight-through	R5 IM64 1	No
6	Output R6	Dwell 100ms	R6 CB Fail Time1	No
7	Output R7	Straight-through	R7 Cntl CB Close	No
8	Output R8	Straight-through	R8 Cntl CB Trip	No
9	Output R9	Dwell 100ms	R9 Trip A	No
10	Output R10	Dwell 100ms	R10 Trip B	No
11	Output R11	Dwell 100ms	R11 Trip C	No
12	Output R12	Straight-through	R12 AR in Prog	No
13	Output R13	Straight-through	R13 SuccessClose	No
14	Output R14	Straight-through	R14 AR Lockout	No
15	Output R15	Straight-through	R15 AR InService	No
16	Output R16	Straight-through	R16 Aid 1 Send	No
17	Output R17	Dwell 100ms	R17 Trip A	Yes
18	Output R18	Dwell 100ms	R18 Trip B	Yes
19	Output R19	Dwell 100ms	R19 Trip C	Yes

Relay Contact No	P443 Option D Relay Text	P443 Option D Relay Conditioner	Function	High break contact?
20	Output R20	Dwell 100ms	R20 Any Trip	Yes
21	Output R21	Dwell 100ms	R21 Trip A	Yes
22	Output R22	Dwell 100ms	R22 Trip B	Yes
23	Output R23	Dwell 100ms	R23 Trip C	Yes
24	Output R24	Dwell 100ms	R24 Any Trip	Yes

Table 12 - Default mappings for P443 (D)

Relay Contact No	P446 Option C Relay Text	P446 Option C Relay Conditioner	Function	High break contact?
1	Output R1	Straight-through	R1 Trip Z1	No
2	Output R2	Straight-through	R2 Any Start	No
3	Output R3	Dwell 100ms	R3 Any Trip	No
4	Output R4	Dwell 500ms	R4 General Alarm	No
5	Output R5	Straight-through	R5 IM64 1	No
6	Output R6	Dwell 100ms	R6 CB1 Fail1Trip	No
7	Output R7	Straight-through	R7 CntlCB1Close	No
8	Output R8	Straight-through	R8 CntlCB2Close	No
9	Output R13	Dwell 100ms	R9 CB1 Trip A	Yes
10	Output R14	Dwell 100ms	R10 CB1 Trip B	Yes
11	Output R15	Dwell 100ms	R11 CB1 Trip C	Yes
12	Output R16	Dwell 100ms	R12 CB2 Trip A	Yes
13	Output R17	Dwell 100ms	R13 CB2 Trip B	Yes
14	Output R18	Dwell 100ms	R14 CB2 Trip C	Yes
15	Output R19	Dwell 100ms	R15 CB1 Trip A	Yes
16	Output R20	Dwell 100ms	R16 CB1 Trip B	Yes
17	Output R21	Dwell 100ms	R17 CB1 Trip C	Yes
18	Output R22	Dwell 100ms	R18 CB2 Trip A	Yes
19	Output R23	Dwell 100ms	R19 CB2 Trip B	Yes
20	Output R24	Dwell 100ms	R20 CB2 Trip C	Yes

Table 13 - Default mappings for P446 (C)

Relay Contact No	P446 Option D Relay Text	P446 Option D Relay Conditioner	Function	High break contact?
1	Output R1	Straight-through	R1 Trip Z1	No
2	Output R2	Straight-through	R2 Any Start	No
3	Output R3	Dwell 100ms	R3 Any Trip	No
4	Output R4	Dwell 500ms	R4 General Alarm	No
5	Output R5	Straight-through	R5 IM64 1	No
6	Output R6	Dwell 100ms	R6 CB1 Fail1Trip	No
7	Output R7	Straight-through	R7 Cntl CB1 Close	No

Relay Contact No	P446 Option D Relay Text	P446 Option D Relay Conditioner	Function	High break contact?
8	Output R8	Straight-through	R8 Cntl CB1 Trip	No
9	Output R9	Dwell 100ms	R9 CB1 Trip A	No
10	Output R10	Dwell 100ms	R10 CB1 Trip B	No
11	Output R11	Dwell 100ms	R11 CB1 Trip C	No
12	Output R12	Straight-through	R12 AR in Prog	No
13	Output R13	Straight-through	R13 CntlCB2Close	No
14	Output R14	Straight-through	R14 Cntl CB2Trip	No
15	Output R15	Dwell 100ms	R15 CB2 Fail1Trip	No
16	Output R16	Straight-through	R16 Aid 1 Send	No
17	Output R17	Dwell 100ms	R17 CB1 Trip A	Yes
18	Output R18	Dwell 100ms	R18 CB1 Trip B	Yes
19	Output R19	Dwell 100ms	R19 CB1 Trip C	Yes
20	Output R20	Dwell 100ms	R20 CB1 Trip 3ph	Yes
21	Output R21	Dwell 100ms	R21 CB2 Trip A	Yes
22	Output R22	Dwell 100ms	R22 CB2 Trip B	Yes
23	Output R23	Dwell 100ms	R23 CB2 Trip C	Yes
24	Output R24	Dwell 100ms	R24 CB2 Trip 3ph	Yes

Note *A fault record can be generated by connecting one or a number of contacts to the “Fault Record Trigger” in PSL. It is recommended that the triggering contact is self reset and not latching. If a latching contact is used the fault record is not be generated until the contact has fully reset.*

Table 14 - Default mappings for P446 (D)

2.5 Programmable LED Output Mappings

The default mappings for each of the programmable LEDs are as shown in the following tables:

LED No	LED Input Connection/Text	Latched	P443 LED Function Indication
1	LED 1 Red	Yes	Dist Inst Trip
2	LED 2 Red	Yes	Dist Delay Trip
3	LED 3 Red	Yes	Aided DEF Trip
4	LED 4 Red	No	Aided Dir Trip
5	LED 5 Red	No	Zone 4 Trip
6	LED 6 Red	No	AR in Progress
7	LED 7 Grn.	No	AR Lockout
8	LED 8 Red	No	AR in Service
9	FnKey LED1 Red	No	Not Mapped
10	FnKey LED2 Red	No	Not Mapped
11	FnKey LED3 Red	No	Not Mapped
12	FnKey LED4 Red	No	Not Mapped

LED No	LED Input Connection/Text	Latched	P443 LED Function Indication
13	FnKey LED5 Red	No	Not Mapped
14	FnKey LED6 Red	No	Not Mapped
15	FnKey LED7 Red	No	Not Mapped
16	FnKey LED8 Red	No	Not Mapped
17	FnKey LED9 Red	No	Not Mapped
18	FnKey LED10 Red	No	Not Mapped

Table 15 - Default mappings for P443

LED No	LED Input Connection/Text	Latched	P446 LED Function Indication
1	Red	Yes	Dist Inst Trip
2	Red	Yes	Dist Delay Trip
3	Red	Yes	Aided DEF Trip
4	Red	Yes	Aided Dir Trip
5	Amber	No	Any start
6	Red	Yes	Zone 4 Trip
7	Amber	No	Test Loopback
8	Amber	No	AR in Service
F1	Red	No	CB1 A Open
	Green	No	CB1 A Closed
F2	Red	No	CB1 B Open
	Green	No	CB1 B Closed
F3	Red	No	CB1 C Open
	Green	No	CB1 C Closed
F4	Red	No	CB1 AR Lockout
F5	Green	No	CB1 AR Successful
	Amber	No	CB1 ARIP
F6	Red	No	CB2 A Open
	Green	No	CB2 A Closed
F7	Red	No	CB2 B Open
	Green	No	CB2 B Closed
F8	Red	No	CB2 C Open
	Green	No	CB2 C Closed
F9	Red	No	CB2 AR Lockout
F10	Green	No	CB2 AR Successful
	Amber	No	CB2 ARIP

Table 16 - Default mappings for P446

2.6 Fault Recorder Start Mappings

The default mappings for the signal which initiates a fault record is as shown in the following table:

Initiating Signal	Fault Trigger
DDB Any Trip (522)	Initiate fault recording from main protection trip

Table 17 - Fault recorder start mappings

2.7 PSL DATA column

The MiCOM P443/P446 relay contains a PSL DATA column that can be used to track PSL modifications. A total of 12 cells are contained in the PSL DATA column, 3 for each setting group. The function for each cell is shown below:

Grp. PSL Ref.	When downloading a PSL to the relay, the user will be prompted to enter which group the PSL is for and a reference identifier. The first 32 characters of the reference ID will be displayed in this cell. The ↑ and ↓ keys can be used to scroll through 32 characters as only 16 can be displayed at any one time.
18 Nov 2002 08:59:32.047	This cell displays the date and time when the PSL was down loaded to the relay.
Grp. 1 PSL ID - 2062813232	This is a unique number for the PSL that has been entered. Any change in the PSL will result in a different number being displayed.

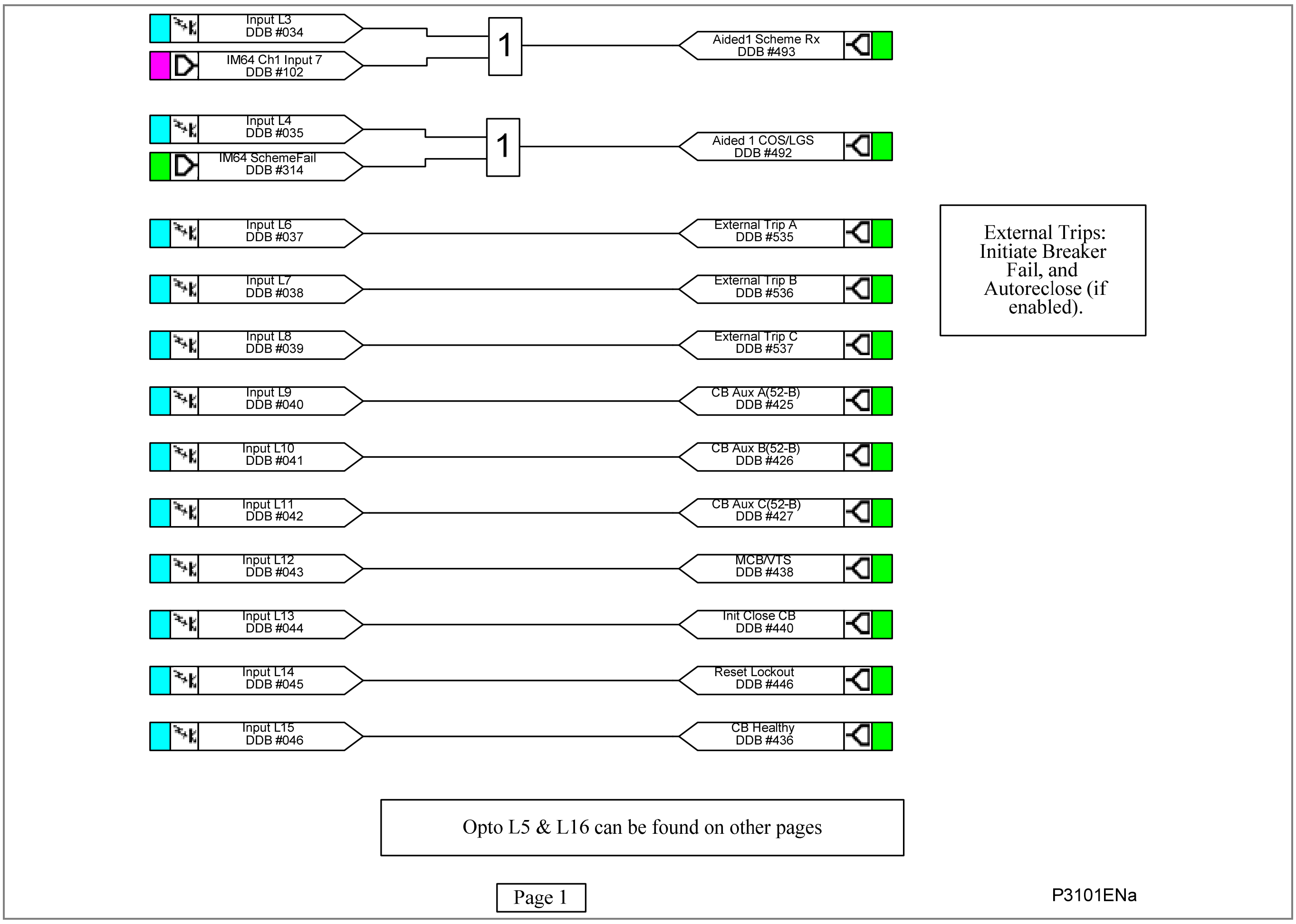
Note *The above cells are repeated for each setting group.*

Table 18 - PSL data column functions

Notes:

P443 WITH STANDARD CONTACTS PSL 24 STD RELAYS

Opto Input Mappings

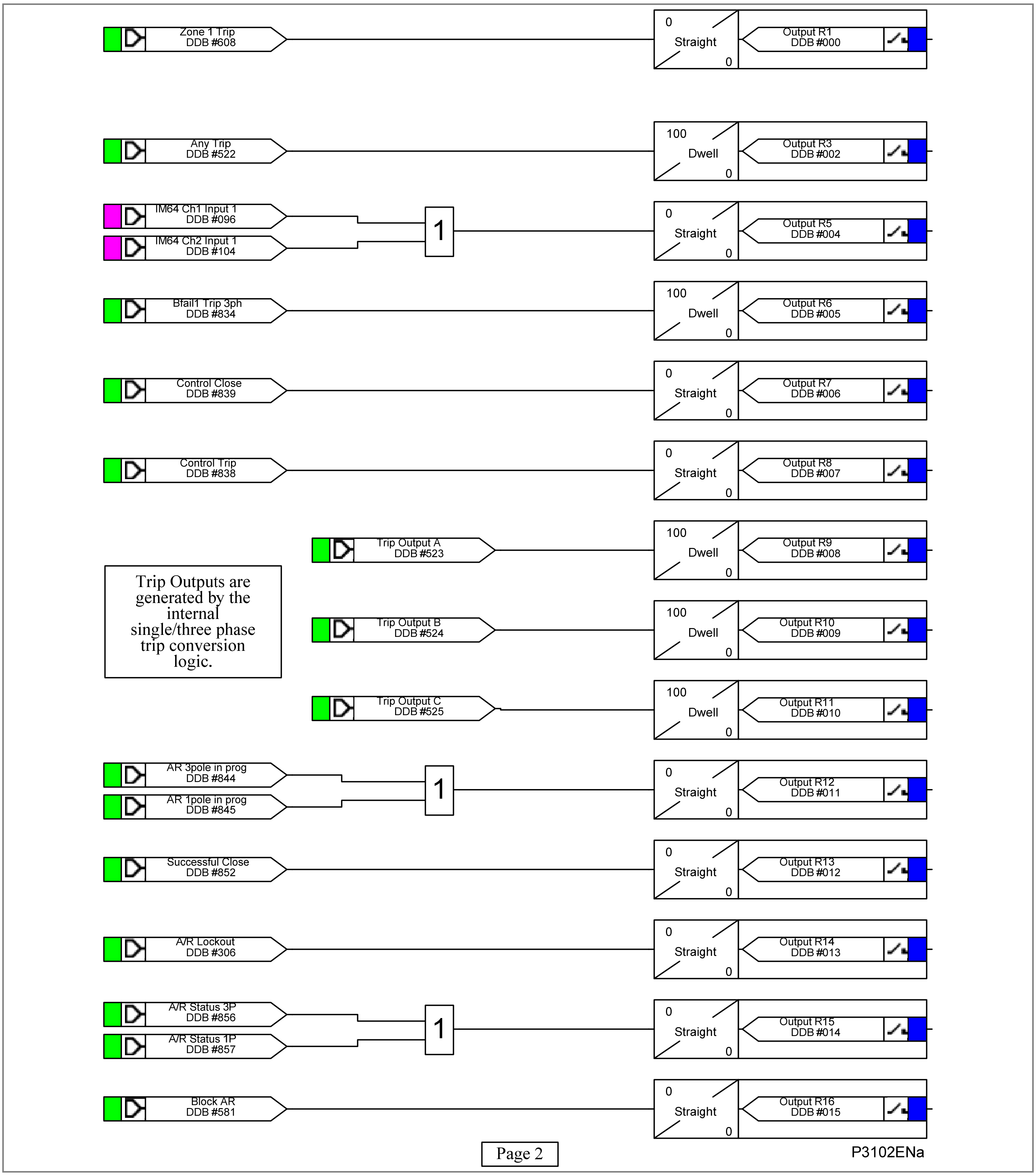

Input L3
DDB #034
IM64 Ch1 Input 7
DDB #102
1
Aided1 Scheme Rx
DDB #493
Input L4
DDB #035
IM64 SchemeFail
DDB #314
1
Aided 1 COS/LGS
DDB #492
Input L6
DDB #037
External Trip A
DDB #535
Input L7
DDB #038
External Trip B
DDB #536
Input L8
DDB #039
External Trip C
DDB #537
Input L9
DDB #040
CB Aux A(52-B)
DDB #425
Input L10
DDB #041
CB Aux B(52-B)
DDB #426
Input L11
DDB #042
CB Aux C(52-B)
DDB #427
Input L12
DDB #043
MCB/VTS
DDB #438
Input L13
DDB #044
Init Close CB
DDB #440
Input L14
DDB #045
Reset Lockout
DDB #446
Input L15
DDB #046
CB Healthy
DDB #436
Page 1

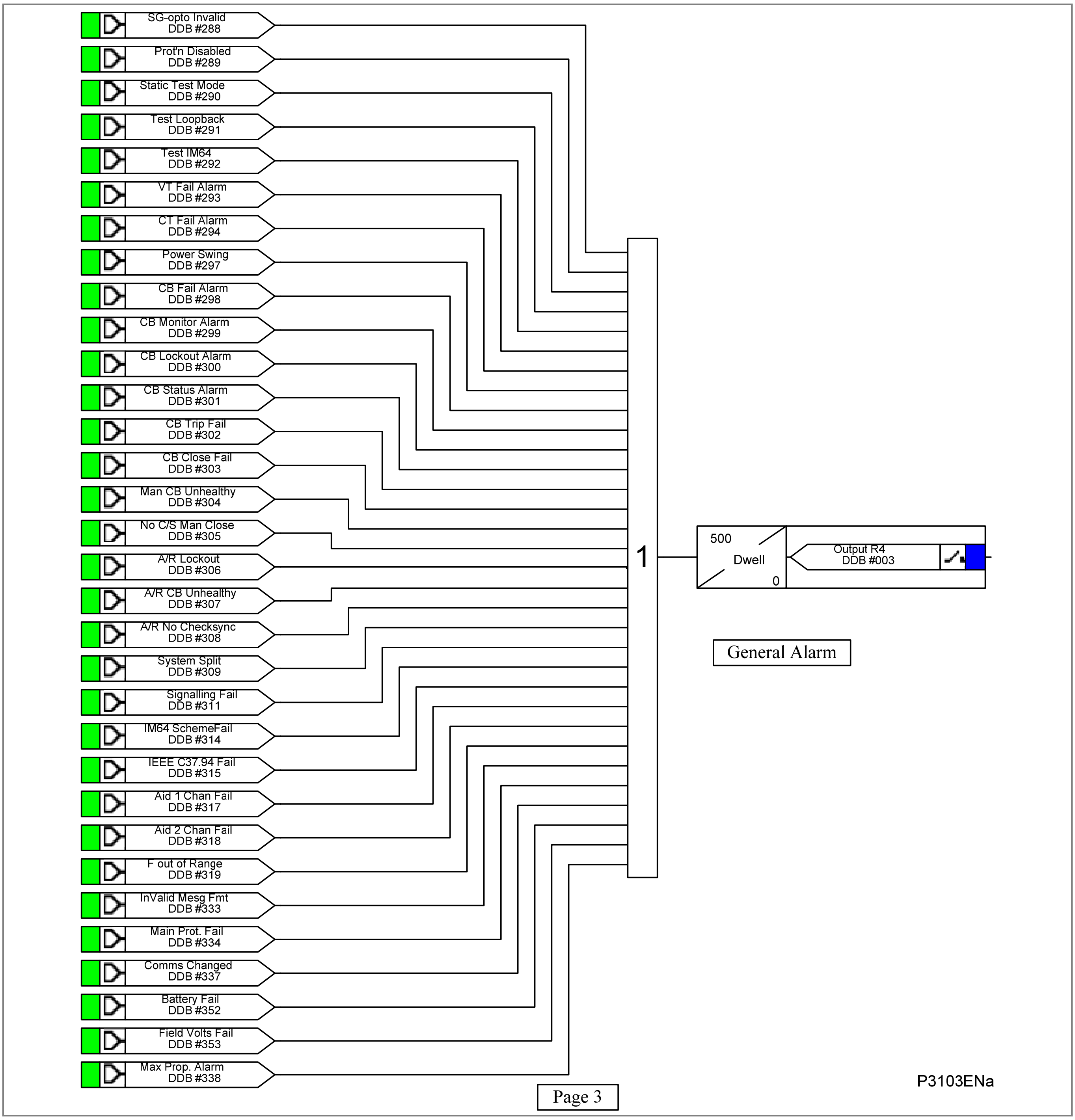
External Trips: Initiate Breaker Fail, and Autoreclose (if enabled).

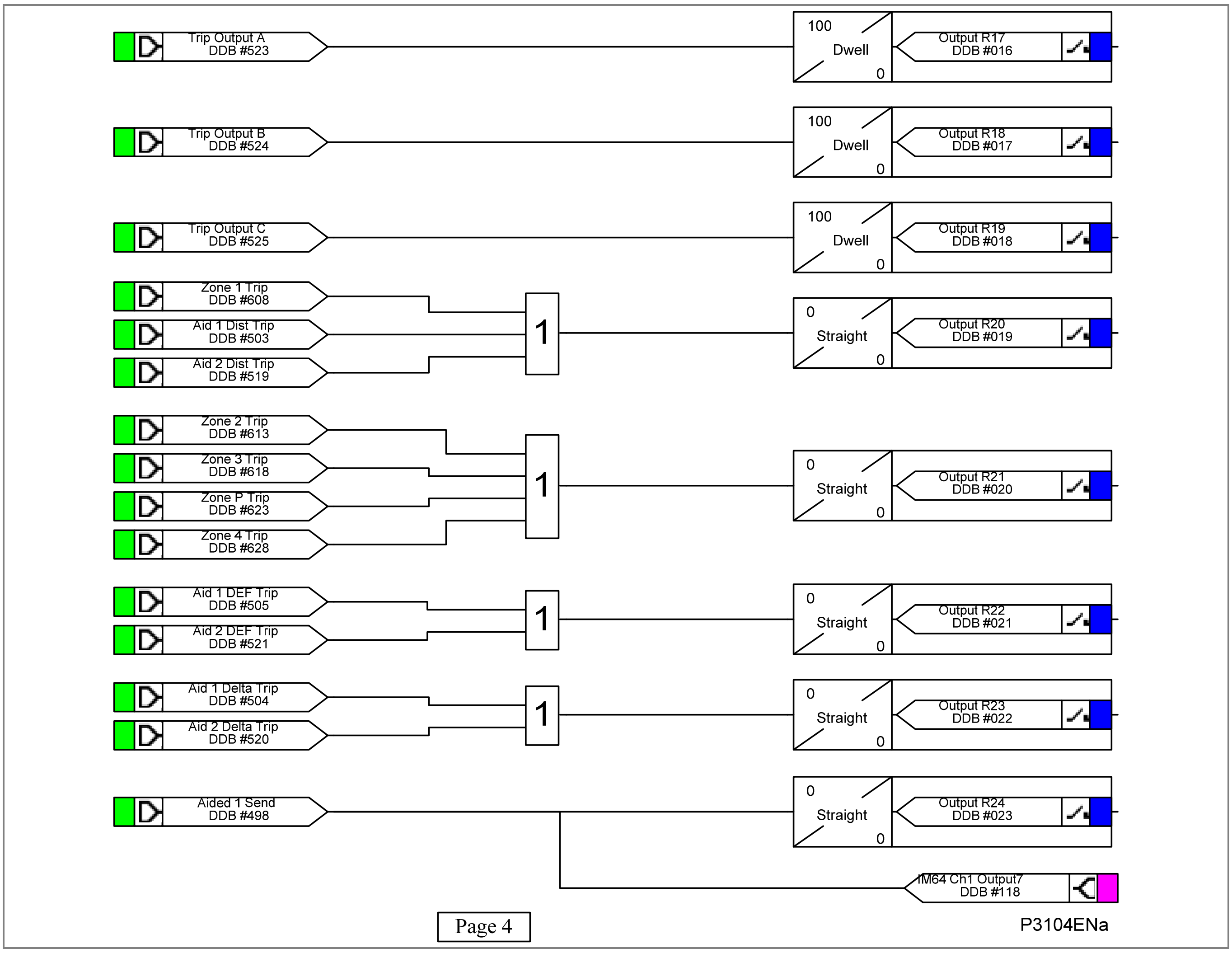
Opto L5 & L16 can be found on other pages

P3101ENa

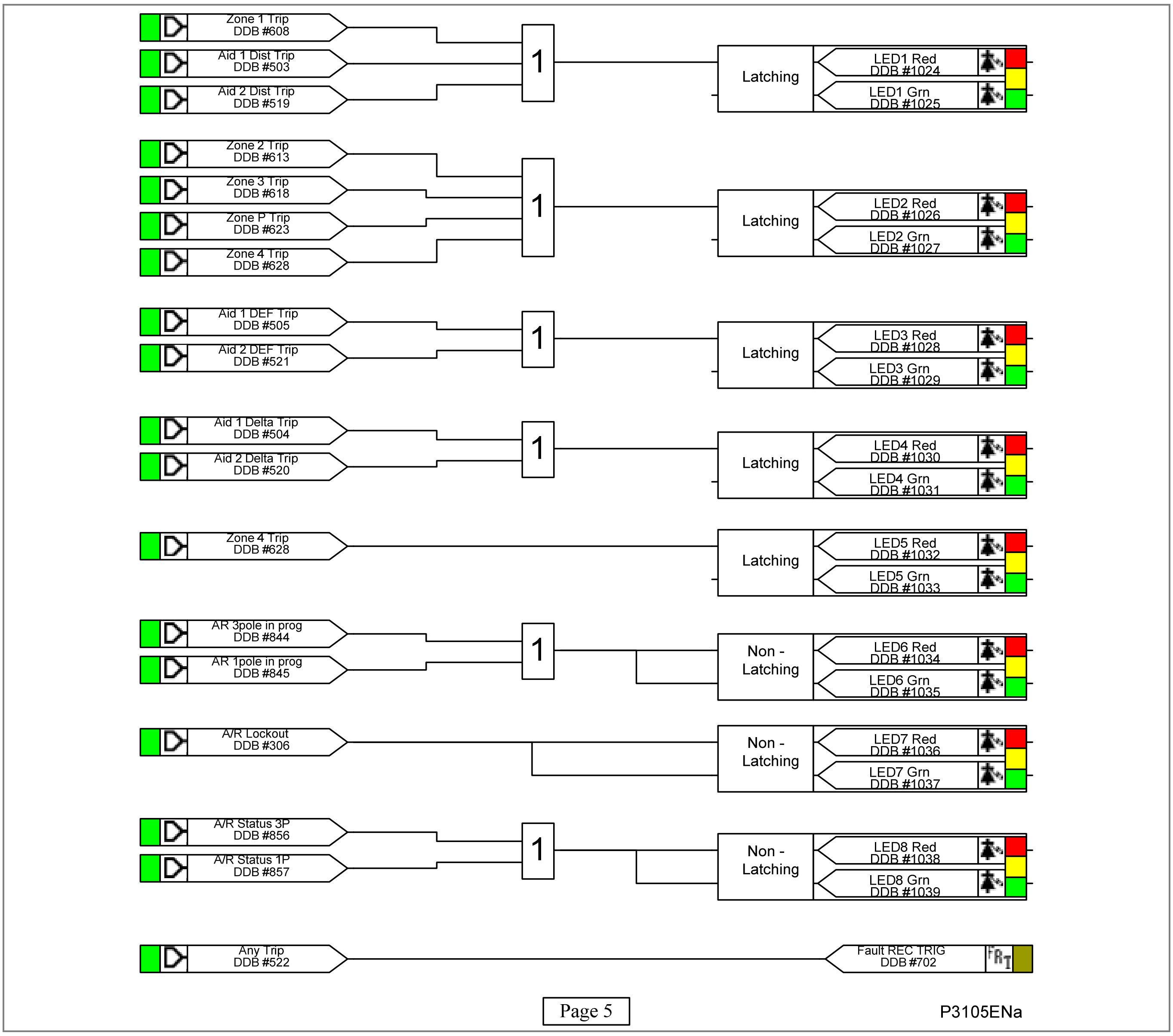
Output Contacts


Zone 1 Trip DDB #608
0 Straight 0
Output R1 DDB #000
Any Trip DDB #522
100 Dwell 0
Output R3 DDB #002
IM64 Ch1 Input 1 DDB #096
IM64 Ch2 Input 1 DDB #104
1
0 Straight 0
Output R5 DDB #004
Bfail1 Trip 3ph DDB #834
100 Dwell 0
Output R6 DDB #005
Control Close DDB #839
0 Straight 0
Output R7 DDB #006
Control Trip DDB #838
0 Straight 0
Output R8 DDB #007
Trip Outputs are generated by the internal single/three phase trip conversion logic.
Trip Output A DDB #523
100 Dwell 0
Output R9 DDB #008
Trip Output B DDB #524
100 Dwell 0
Output R10 DDB #009
Trip Output C DDB #525
100 Dwell 0
Output R11 DDB #010
AR 3pole in prog DDB #844
AR 1pole in prog DDB #845
1
0 Straight 0
Output R12 DDB #011
Successful Close DDB #852
0 Straight 0
Output R13 DDB #012
A/R Lockout DDB #306
0 Straight 0
Output R14 DDB #013
A/R Status 3P DDB #856
A/R Status 1P DDB #857
1
0 Straight 0
Output R15 DDB #014
Block AR DDB #581
0 Straight 0
Output R16 DDB #015
Page 2
P3102ENa


SG-opto Invalid DDB #288
Prot'n Disabled DDB #289
Static Test Mode DDB #290
Test Loopback DDB #291
Test IM64 DDB #292
VT Fail Alarm DDB #293
CT Fail Alarm DDB #294
Power Swing DDB #297
CB Fail Alarm DDB #298
CB Monitor Alarm DDB #299
CB Lockout Alarm DDB #300
CB Status Alarm DDB #301
CB Trip Fail DDB #302
CB Close Fail DDB #303
Man CB Unhealthy DDB #304
No C/S Man Close DDB #305
A/R Lockout DDB #306
A/R CB Unhealthy DDB #307
A/R No Checksync DDB #308
System Split DDB #309
Signalling Fail DDB #311
IM64 SchemeFail DDB #314
IEEE C37.94 Fail DDB #315
Aid 1 Chan Fail DDB #317
Aid 2 Chan Fail DDB #318
F out of Range DDB #319
InValid Mesg Fmt DDB #333
Main Prot. Fail DDB #334
Comms Changed DDB #337
Battery Fail DDB #352
Field Volts Fail DDB #353
Max Prop. Alarm DDB #338
1
500
Dwell
0
Output R4 DDB #003
General Alarm
Page 3
P3103ENa


Trip Output A
DDB #523
100
Dwell
0
Output R17
DDB #016
Trip Output B
DDB #524
100
Dwell
0
Output R18
DDB #017
Trip Output C
DDB #525
100
Dwell
0
Output R19
DDB #018
Zone 1 Trip
DDB #608
Aid 1 Dist Trip
DDB #503
Aid 2 Dist Trip
DDB #519
1
0
Straight
0
Output R20
DDB #019
Zone 2 Trip
DDB #613
Zone 3 Trip
DDB #618
Zone P Trip
DDB #623
Zone 4 Trip
DDB #628
1
0
Straight
0
Output R21
DDB #020
Aid 1 DEF Trip
DDB #505
Aid 2 DEF Trip
DDB #521
1
0
Straight
0
Output R22
DDB #021
Aid 1 Delta Trip
DDB #504
Aid 2 Delta Trip
DDB #520
1
0
Straight
0
Output R23
DDB #022
Aided 1 Send
DDB #498
0
Straight
0
Output R24
DDB #023
IM64 Ch1 Output7
DDB #118
Page 4
P3104ENa

LEDs


Zone 1 Trip DDB #608
Aid 1 Dist Trip DDB #503
Aid 2 Dist Trip DDB #519
1
Latching
LED1 Red DDB #1024
LED1 Grn DDB #1025
Zone 2 Trip DDB #613
Zone 3 Trip DDB #618
Zone P Trip DDB #623
Zone 4 Trip DDB #628
1
Latching
LED2 Red DDB #1026
LED2 Grn DDB #1027
Aid 1 DEF Trip DDB #505
Aid 2 DEF Trip DDB #521
1
Latching
LED3 Red DDB #1028
LED3 Grn DDB #1029
Aid 1 Delta Trip DDB #504
Aid 2 Delta Trip DDB #520
1
Latching
LED4 Red DDB #1030
LED4 Grn DDB #1031
Zone 4 Trip DDB #628
Latching
LED5 Red DDB #1032
LED5 Grn DDB #1033
AR 3pole in prog DDB #844
AR 1pole in prog DDB #845
1
Non - Latching
LED6 Red DDB #1034
LED6 Grn DDB #1035
A/R Lockout DDB #306
Non - Latching
LED7 Red DDB #1036
LED7 Grn DDB #1037
A/R Status 3P DDB #856
A/R Status 1P DDB #857
1
Non - Latching
LED8 Red DDB #1038
LED8 Grn DDB #1039
Any Trip DDB #522
Fault REC TRIG DDB #702
FRT
Page 5
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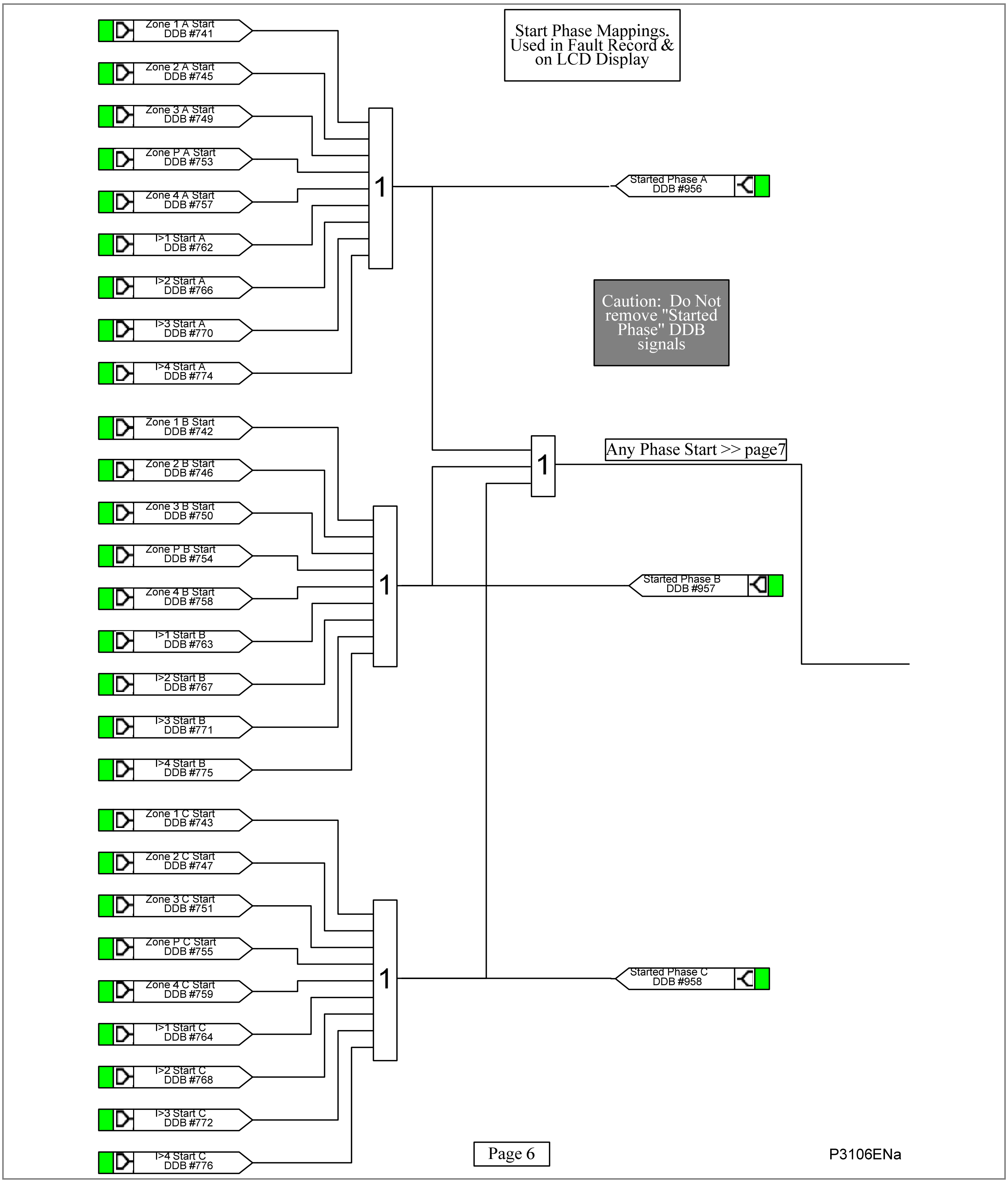
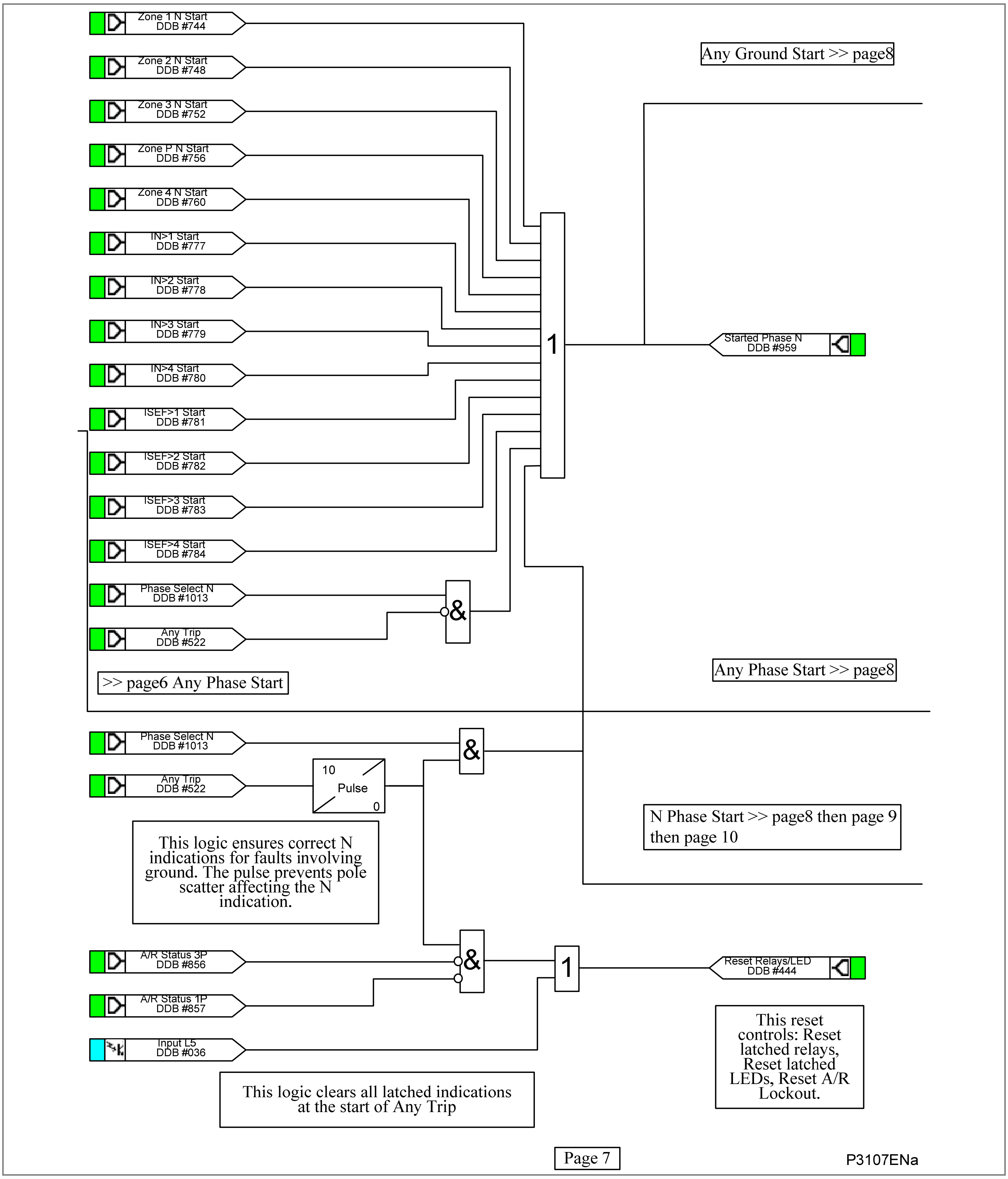
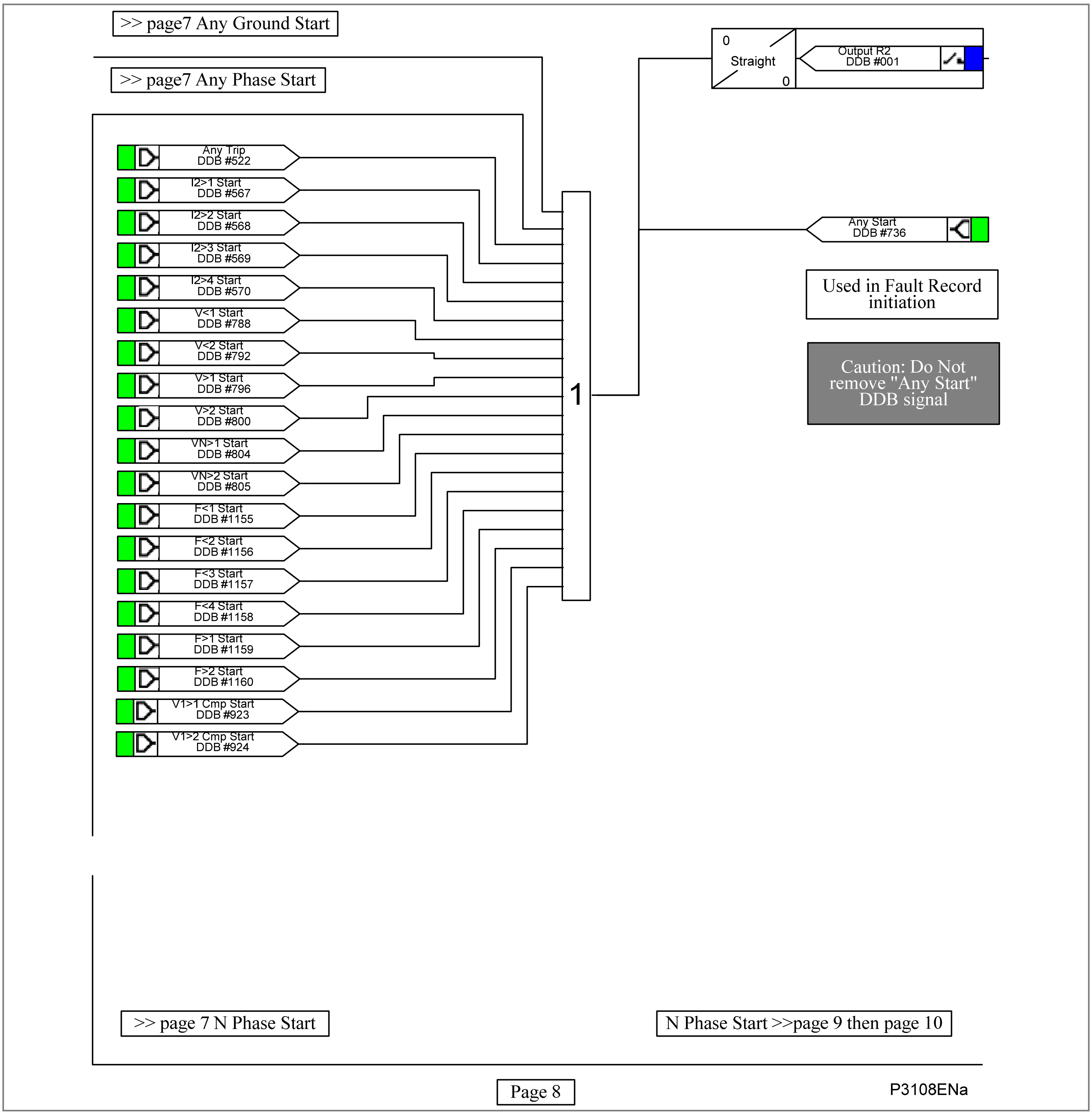
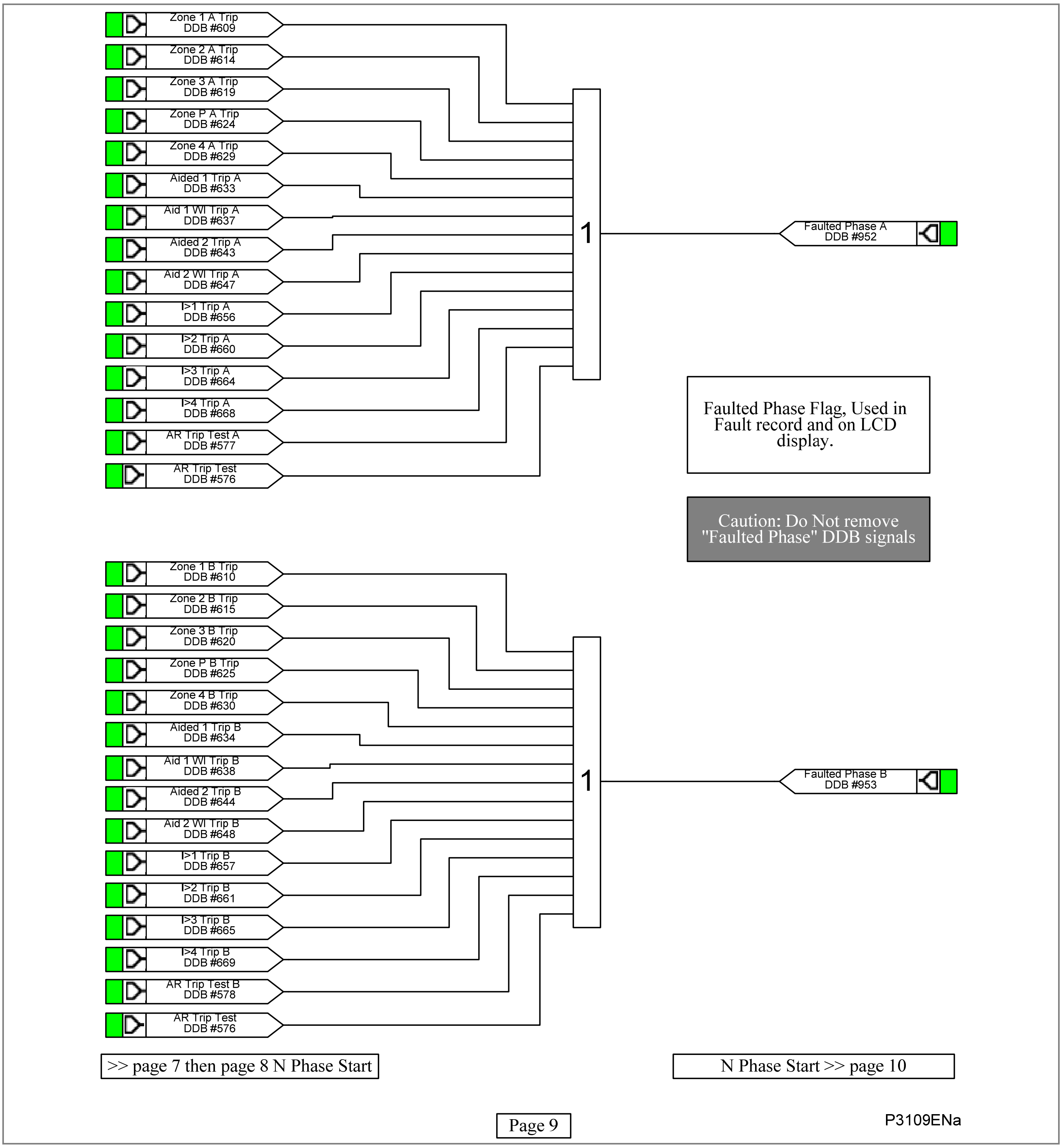
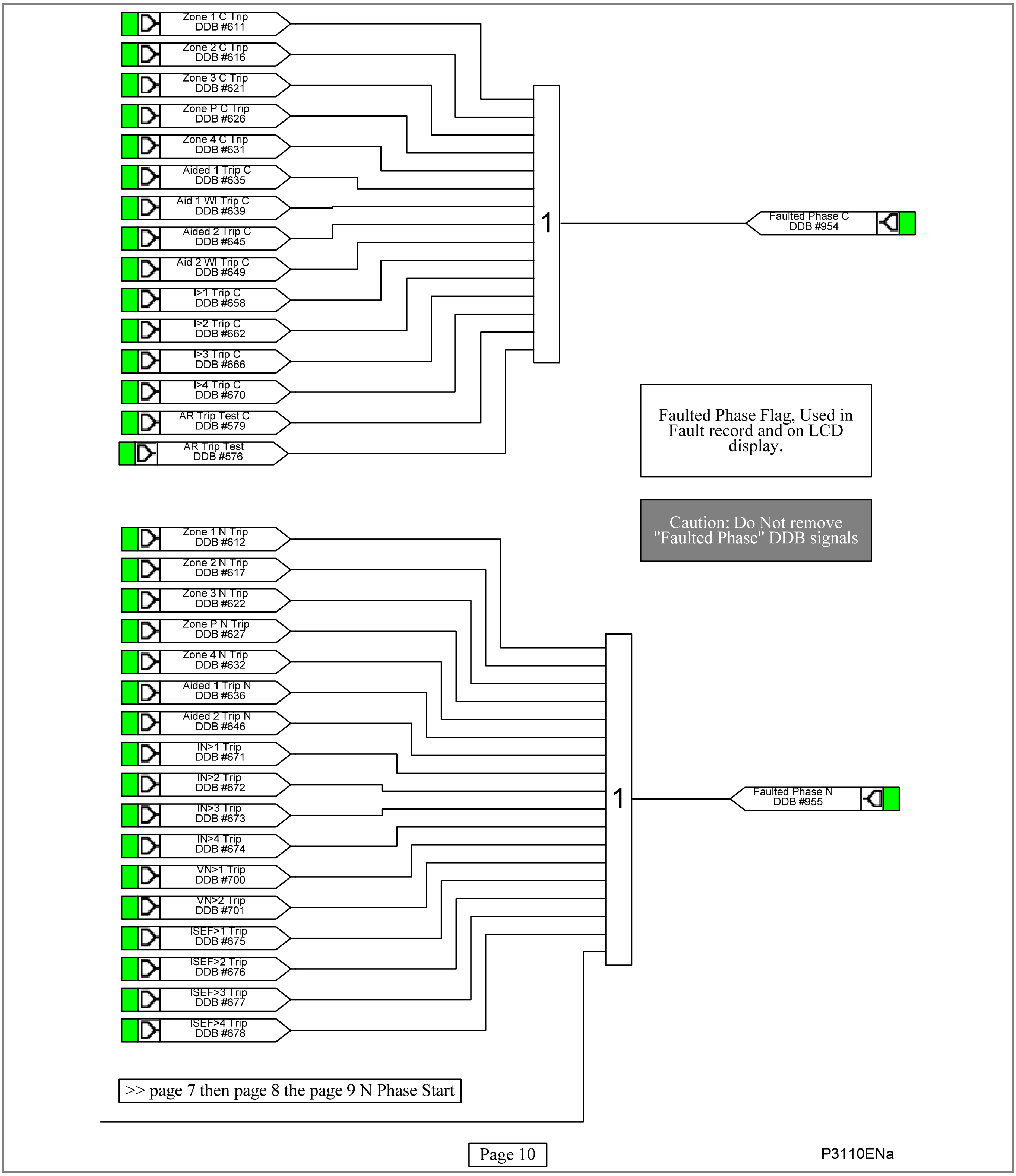
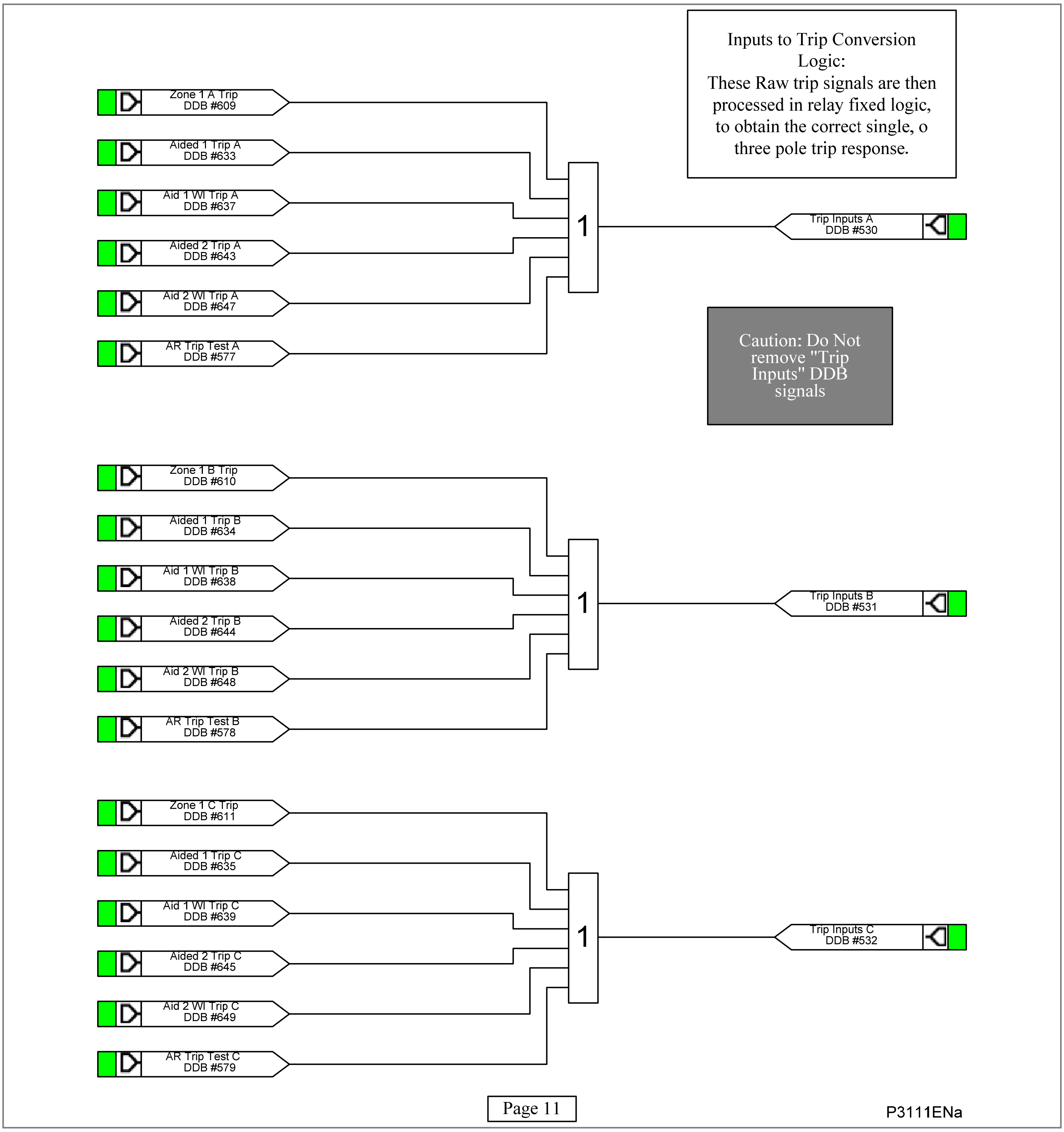

Zone 1 A Start DDB #741
Zone 2 A Start DDB #745
Zone 3 A Start DDB #749
Zone P A Start DDB #753
Zone 4 A Start DDB #757
I>1 Start A DDB #762
I>2 Start A DDB #766
I>3 Start A DDB #770
I>4 Start A DDB #774
Zone 1 B Start DDB #742
Zone 2 B Start DDB #746
Zone 3 B Start DDB #750
Zone P B Start DDB #754
Zone 4 B Start DDB #758
I>1 Start B DDB #763
I>2 Start B DDB #767
I>3 Start B DDB #771
I>4 Start B DDB #775
Zone 1 C Start DDB #743
Zone 2 C Start DDB #747
Zone 3 C Start DDB #751
Zone P C Start DDB #755
Zone 4 C Start DDB #759
I>1 Start C DDB #764
I>2 Start C DDB #768
I>3 Start C DDB #772
I>4 Start C DDB #776
1
1
1
1
Start Phase Mappings. Used in Fault Record & on LCD Display
Started Phase A DDB #956
Caution: Do Not remove "Started Phase" DDB signals
Any Phase Start >> page7
Started Phase B DDB #957
Started Phase C DDB #958
Page 6
P3106ENa

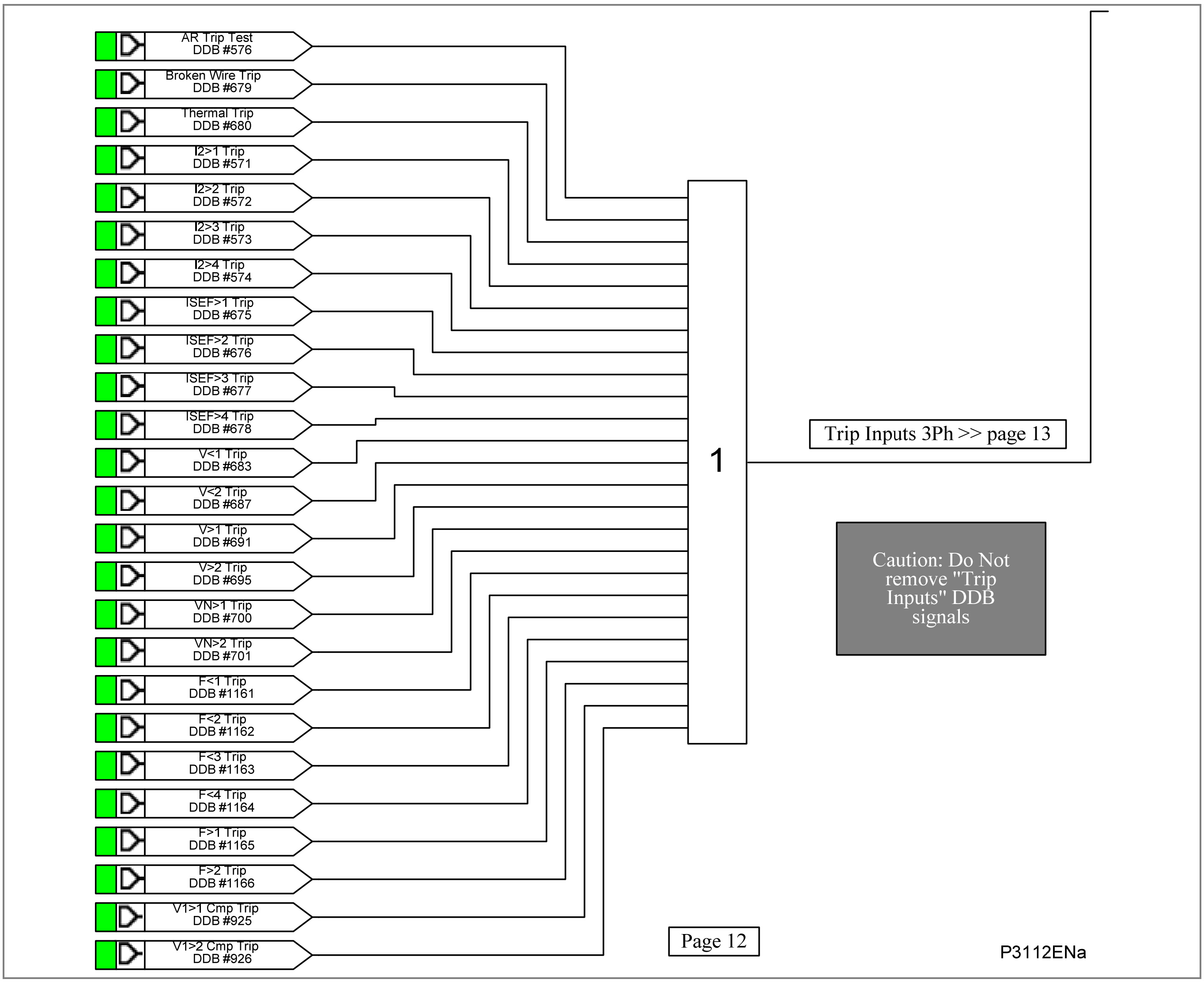

Zone 1 N Start DDB #744
Zone 2 N Start DDB #748
Zone 3 N Start DDB #752
Zone P N Start DDB #756
Zone 4 N Start DDB #760
IN>1 Start DDB #777
IN>2 Start DDB #778
IN>3 Start DDB #779
IN>4 Start DDB #780
ISEF>1 Start DDB #781
ISEF>2 Start DDB #782
ISEF>3 Start DDB #783
ISEF>4 Start DDB #784
Phase Select N DDB #1013
Any Trip DDB #522
&
1
Started Phase N DDB #959
Any Ground Start >> page8
Any Phase Start >> page8
>> page6 Any Phase Start
Phase Select N DDB #1013
Any Trip DDB #522
10
Pulse
0
&
N Phase Start >> page8 then page 9 then page 10
This logic ensures correct N indications for faults involving ground. The pulse prevents pole scatter affecting the N indication.
A/R Status 3P DDB #856
A/R Status 1P DDB #857
Input L5 DDB #036
&
1
Reset Relays/LED DDB #444
This reset controls: Reset latched relays, Reset latched LEDs, Reset A/R Lockout.
This logic clears all latched indications at the start of Any Trip
Page 7
P3107ENa

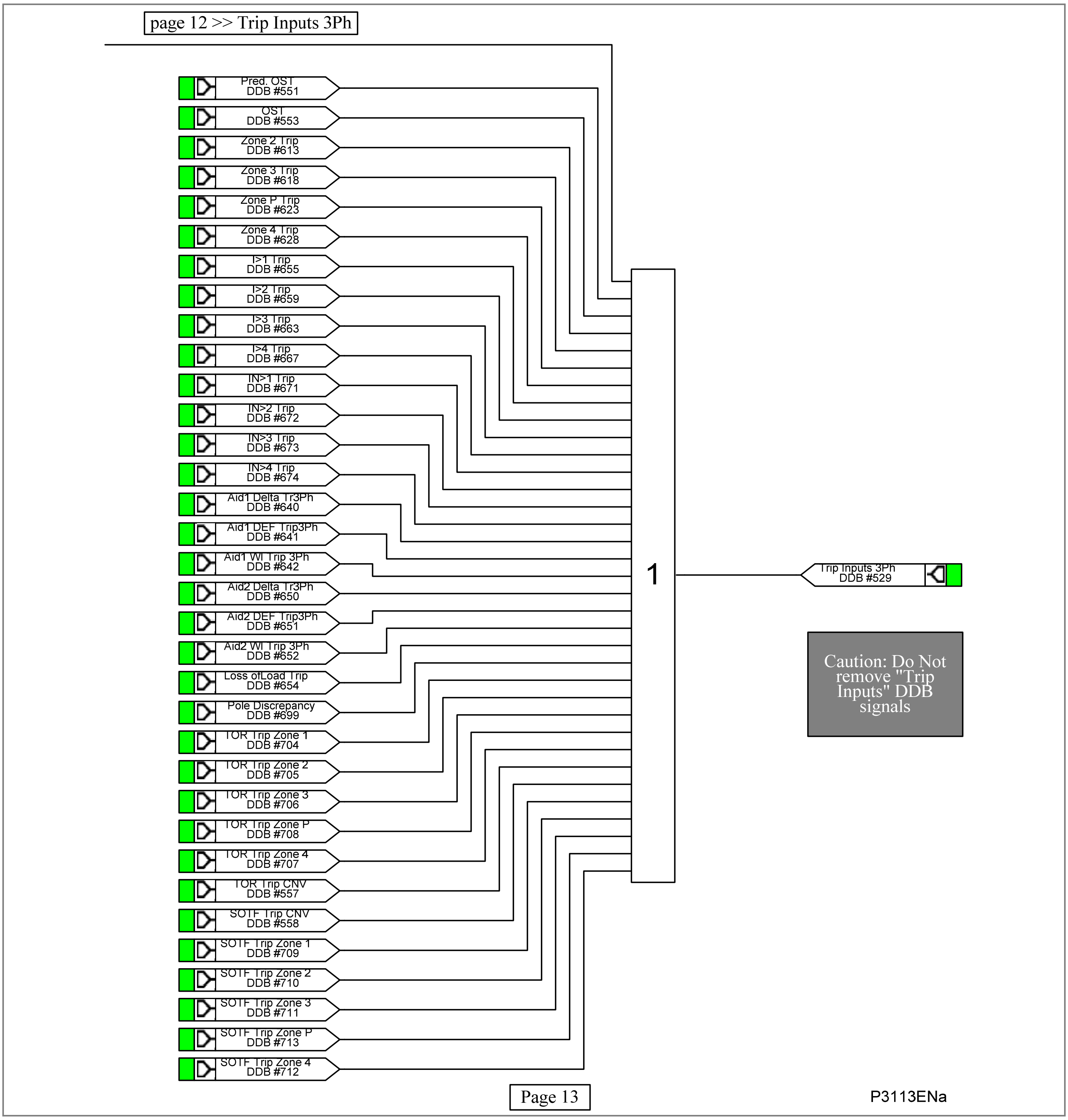

>> page7 Any Ground Start
>> page7 Any Phase Start
Any Trip DDB #522
I2>1 Start DDB #567
I2>2 Start DDB #568
I2>3 Start DDB #569
I2>4 Start DDB #570
V<1 Start DDB #788
V<2 Start DDB #792
V>1 Start DDB #796
V>2 Start DDB #800
VN>1 Start DDB #804
VN>2 Start DDB #805
F<1 Start DDB #1155
F<2 Start DDB #1156
F<3 Start DDB #1157
F<4 Start DDB #1158
F>1 Start DDB #1159
F>2 Start DDB #1160
V1>1 Cmp Start DDB #923
V1>2 Cmp Start DDB #924
1
0
Straight
0
Output R2 DDB #001
Any Start DDB #736
Used in Fault Record initiation
Caution: Do Not remove "Any Start" DDB signal
>> page 7 N Phase Start
N Phase Start >>page 9 then page 10
Page 8
P3108ENa

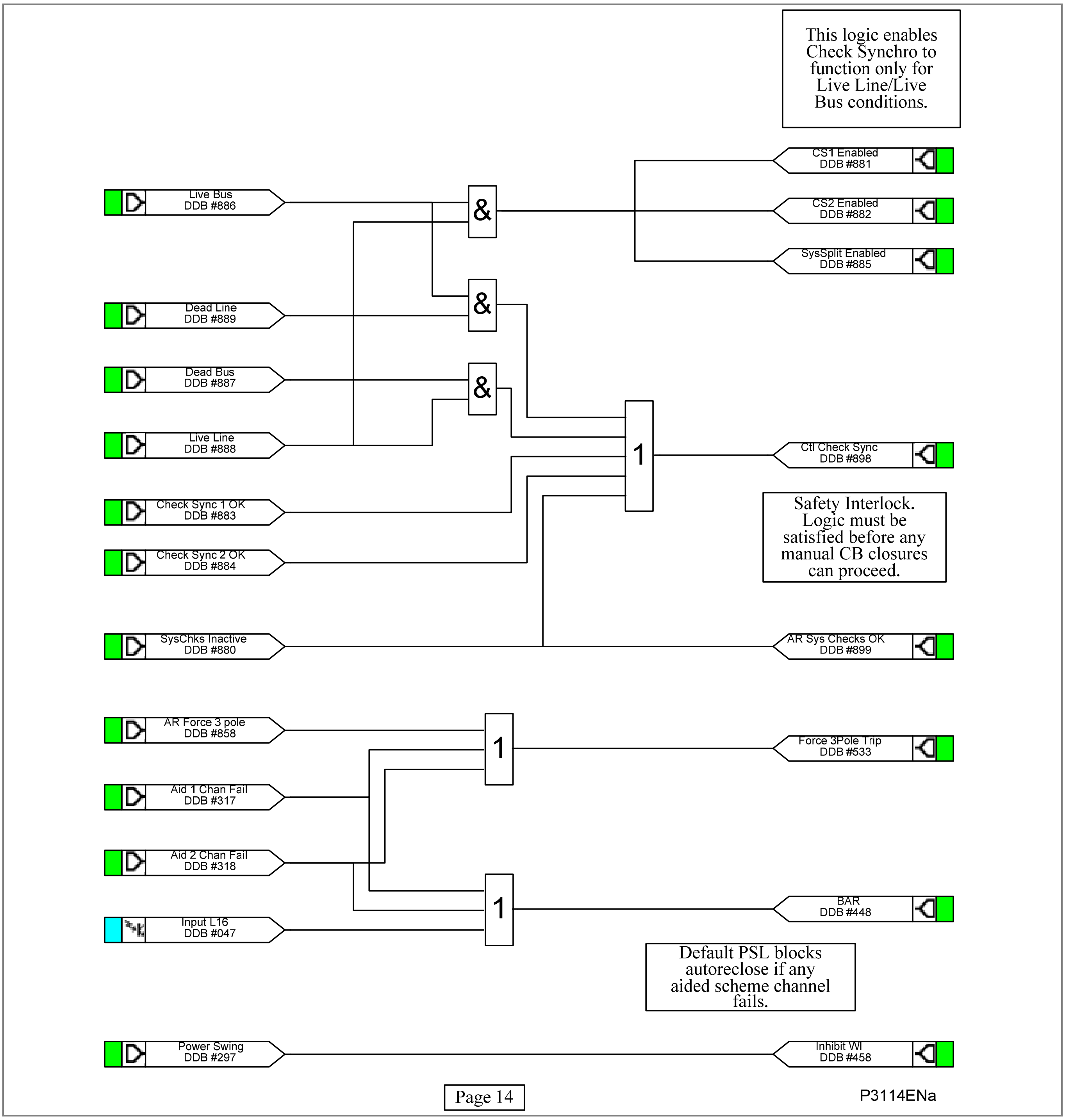

Zone 1 A Trip DDB #609
Zone 2 A Trip DDB #614
Zone 3 A Trip DDB #619
Zone P A Trip DDB #624
Zone 4 A Trip DDB #629
Aided 1 Trip A DDB #633
Aid 1 WI Trip A DDB #637
Aided 2 Trip A DDB #643
Aid 2 WI Trip A DDB #647
I>1 Trip A DDB #656
I>2 Trip A DDB #660
I>3 Trip A DDB #664
I>4 Trip A DDB #668
AR Trip Test A DDB #577
AR Trip Test DDB #576
1
Faulted Phase A DDB #952
Faulted Phase Flag, Used in Fault record and on LCD display.
Caution: Do Not remove "Faulted Phase" DDB signals
Zone 1 B Trip DDB #610
Zone 2 B Trip DDB #615
Zone 3 B Trip DDB #620
Zone P B Trip DDB #625
Zone 4 B Trip DDB #630
Aided 1 Trip B DDB #634
Aid 1 WI Trip B DDB #638
Aided 2 Trip B DDB #644
Aid 2 WI Trip B DDB #648
I>1 Trip B DDB #657
I>2 Trip B DDB #661
I>3 Trip B DDB #665
I>4 Trip B DDB #669
AR Trip Test B DDB #578
AR Trip Test DDB #576
1
Faulted Phase B DDB #953
>> page 7 then page 8 N Phase Start
N Phase Start >> page 10
Page 9
P3109ENa


Zone 1 C Trip DDB #611
Zone 2 C Trip DDB #616
Zone 3 C Trip DDB #621
Zone P C Trip DDB #626
Zone 4 C Trip DDB #631
Aided 1 Trip C DDB #635
Aid 1 WI Trip C DDB #639
Aided 2 Trip C DDB #645
Aid 2 WI Trip C DDB #649
I>1 Trip C DDB #658
I>2 Trip C DDB #662
I>3 Trip C DDB #666
I>4 Trip C DDB #670
AR Trip Test C DDB #579
AR Trip Test DDB #576
1
Faulted Phase C DDB #954
Faulted Phase Flag, Used in Fault record and on LCD display.
Caution: Do Not remove "Faulted Phase" DDB signals
Zone 1 N Trip DDB #612
Zone 2 N Trip DDB #617
Zone 3 N Trip DDB #622
Zone P N Trip DDB #627
Zone 4 N Trip DDB #632
Aided 1 Trip N DDB #636
Aided 2 Trip N DDB #646
IN>1 Trip DDB #671
IN>2 Trip DDB #672
IN>3 Trip DDB #673
IN>4 Trip DDB #674
VN>1 Trip DDB #700
VN>2 Trip DDB #701
ISEF>1 Trip DDB #675
ISEF>2 Trip DDB #676
ISEF>3 Trip DDB #677
ISEF>4 Trip DDB #678
1
Faulted Phase N DDB #955
>> page 7 then page 8 the page 9 N Phase Start
Page 10
P3110ENa


Inputs to Trip Conversion Logic:
These Raw trip signals are then processed in relay fixed logic, to obtain the correct single, o three pole trip response.
Zone 1 A Trip DDB #609
Aided 1 Trip A DDB #633
Aid 1 WI Trip A DDB #637
Aided 2 Trip A DDB #643
Aid 2 WI Trip A DDB #647
AR Trip Test A DDB #577
1
Trip Inputs A DDB #530
Caution: Do Not remove "Trip Inputs" DDB signals
Zone 1 B Trip DDB #610
Aided 1 Trip B DDB #634
Aid 1 WI Trip B DDB #638
Aided 2 Trip B DDB #644
Aid 2 WI Trip B DDB #648
AR Trip Test B DDB #578
1
Trip Inputs B DDB #531
Zone 1 C Trip DDB #611
Aided 1 Trip C DDB #635
Aid 1 WI Trip C DDB #639
Aided 2 Trip C DDB #645
Aid 2 WI Trip C DDB #649
AR Trip Test C DDB #579
1
Trip Inputs C DDB #532
Page 11
P3111ENa

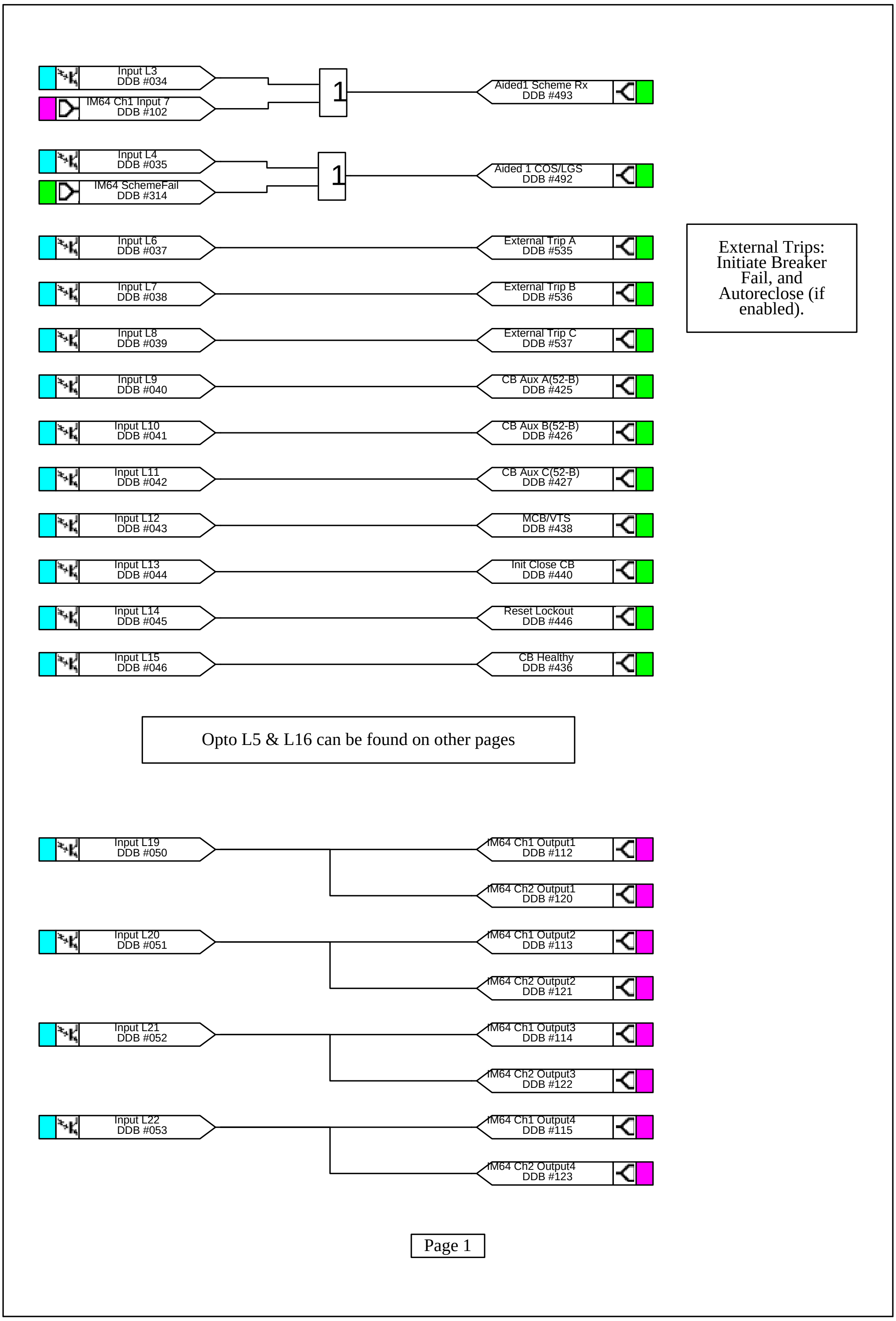

AR Trip Test
DDB #576
Broken Wire Trip
DDB #679
Thermal Trip
DDB #680
I2>1 Trip
DDB #571
I2>2 Trip
DDB #572
I2>3 Trip
DDB #573
I2>4 Trip
DDB #574
ISEF>1 Trip
DDB #675
ISEF>2 Trip
DDB #676
ISEF>3 Trip
DDB #677
ISEF>4 Trip
DDB #678
V<1 Trip
DDB #683
V<2 Trip
DDB #687
V>1 Trip
DDB #691
V>2 Trip
DDB #695
VN>1 Trip
DDB #700
VN>2 Trip
DDB #701
F<1 Trip
DDB #1161
F<2 Trip
DDB #1162
F<3 Trip
DDB #1163
F<4 Trip
DDB #1164
F>1 Trip
DDB #1165
F>2 Trip
DDB #1166
V1>1 Cmp Trip
DDB #925
V1>2 Cmp Trip
DDB #926
1
Trip Inputs 3Ph >> page 13
Caution: Do Not remove "Trip Inputs" DDB signals
Page 12
P3112ENa


page 12 >> Trip Inputs 3Ph
Pred. OST DDB #551
OST DDB #553
Zone 2 Trip DDB #613
Zone 3 Trip DDB #618
Zone P Trip DDB #623
Zone 4 Trip DDB #628
I>1 Trip DDB #655
I>2 Trip DDB #659
I>3 Trip DDB #663
I>4 Trip DDB #667
IN>1 Trip DDB #671
IN>2 Trip DDB #672
IN>3 Trip DDB #673
IN>4 Trip DDB #674
Aid1 Delta Tr3Ph DDB #640
Aid1 DEF Trip3Ph DDB #641
Aid1 WI Trip 3Ph DDB #642
Aid2 Delta Tr3Ph DDB #650
Aid2 DEF Trip3Ph DDB #651
Aid2 WI Trip 3Ph DDB #652
Loss ofLoad Trip DDB #654
Pole Discrepancy DDB #699
TOR Trip Zone 1 DDB #704
TOR Trip Zone 2 DDB #705
TOR Trip Zone 3 DDB #706
TOR Trip Zone P DDB #708
TOR Trip Zone 4 DDB #707
TOR Trip CNV DDB #557
SOTF Trip CNV DDB #558
SOTF Trip Zone 1 DDB #709
SOTF Trip Zone 2 DDB #710
SOTF Trip Zone 3 DDB #711
SOTF Trip Zone P DDB #713
SOTF Trip Zone 4 DDB #712
1
Trip Inputs 3Ph DDB #529
Caution: Do Not remove "Trip Inputs" DDB signals
Page 13
P3113ENa

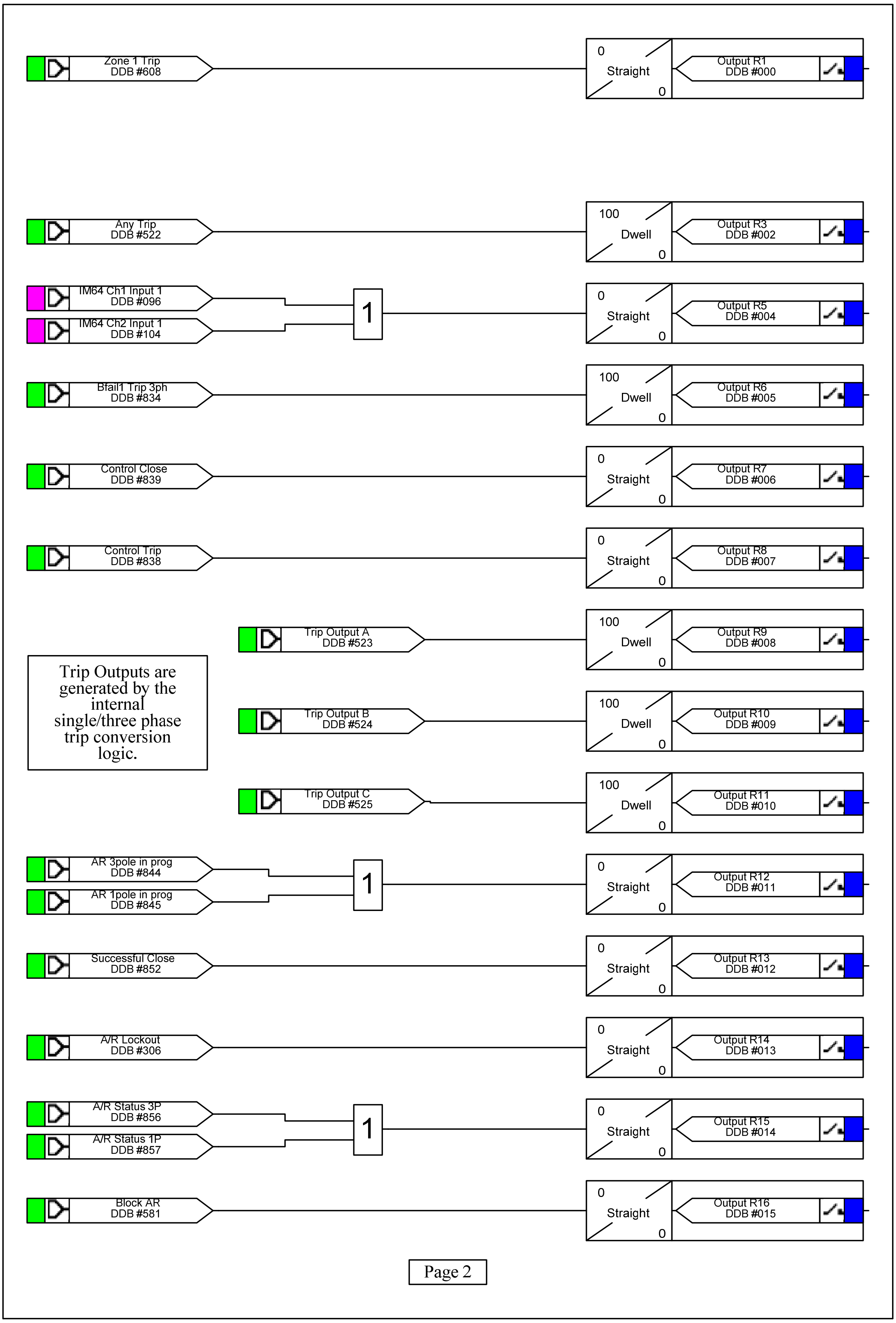

This logic enables Check Synchro to function only for Live Line/Live Bus conditions.
CS1 Enabled DDB #881
CS2 Enabled DDB #882
SysSplit Enabled DDB #885
Live Bus DDB #886
Dead Line DDB #889
Dead Bus DDB #887
Live Line DDB #888
Check Sync 1 OK DDB #883
Check Sync 2 OK DDB #884
SysChks Inactive DDB #880
&
&
&
1
Ctl Check Sync DDB #898
Safety Interlock. Logic must be satisfied before any manual CB closures can proceed.
AR Sys Checks OK DDB #899
AR Force 3 pole DDB #858
Aid 1 Chan Fail DDB #317
Aid 2 Chan Fail DDB #318
Input L16 DDB #047
1
1
Force 3Pole Trip DDB #533
BAR DDB #448
Default PSL blocks autoreclose if any aided scheme channel fails.
Power Swing DDB #297
Inhibit WI DDB #458
Page 14
P3114ENa

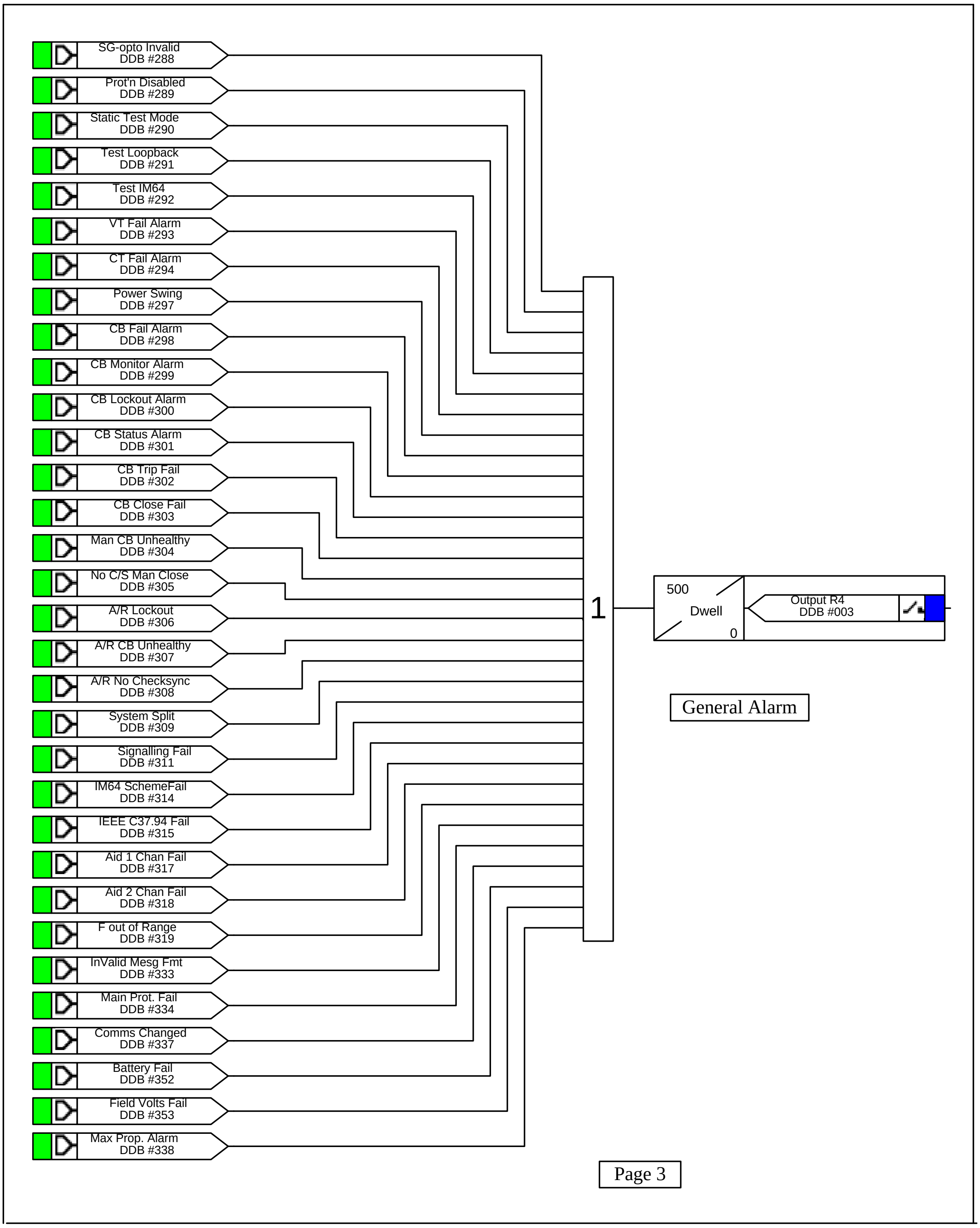
P443 WITH STANDARD CONTACTS PSL 32 STD RELAYS

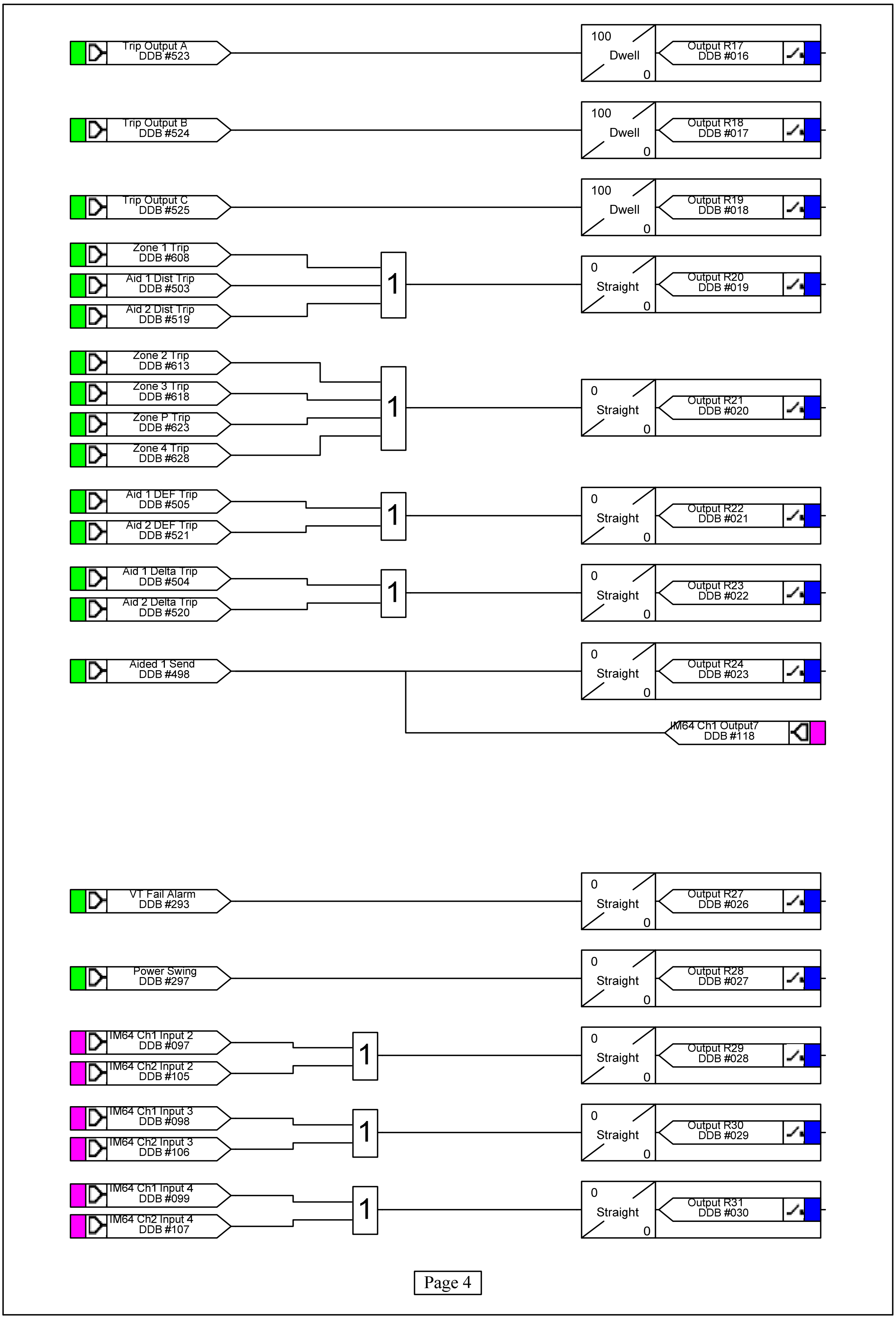
Opto Input Mappings


Input L3
DDB #034
IM64 Ch1 Input 7
DDB #102
1
Aided1 Scheme Rx
DDB #493
Input L4
DDB #035
IM64 SchemeFail
DDB #314
1
Aided 1 COS/LGS
DDB #492
Input L6
DDB #037
External Trip A
DDB #535
Input L7
DDB #038
External Trip B
DDB #536
Input L8
DDB #039
External Trip C
DDB #537
External Trips: Initiate Breaker Fail, and Autoreclose (if enabled).
Input L9
DDB #040
CB Aux A(52-B)
DDB #425
Input L10
DDB #041
CB Aux B(52-B)
DDB #426
Input L11
DDB #042
CB Aux C(52-B)
DDB #427
Input L12
DDB #043
MCB/VTS
DDB #438
Input L13
DDB #044
Init Close CB
DDB #440
Input L14
DDB #045
Reset Lockout
DDB #446
Input L15
DDB #046
CB Healthy
DDB #436
Opto L5 & L16 can be found on other pages
Input L19
DDB #050
IM64 Ch1 Output1
DDB #112
IM64 Ch2 Output1
DDB #120
Input L20
DDB #051
IM64 Ch1 Output2
DDB #113
IM64 Ch2 Output2
DDB #121
Input L21
DDB #052
IM64 Ch1 Output3
DDB #114
IM64 Ch2 Output3
DDB #122
Input L22
DDB #053
IM64 Ch1 Output4
DDB #115
IM64 Ch2 Output4
DDB #123
Page 1

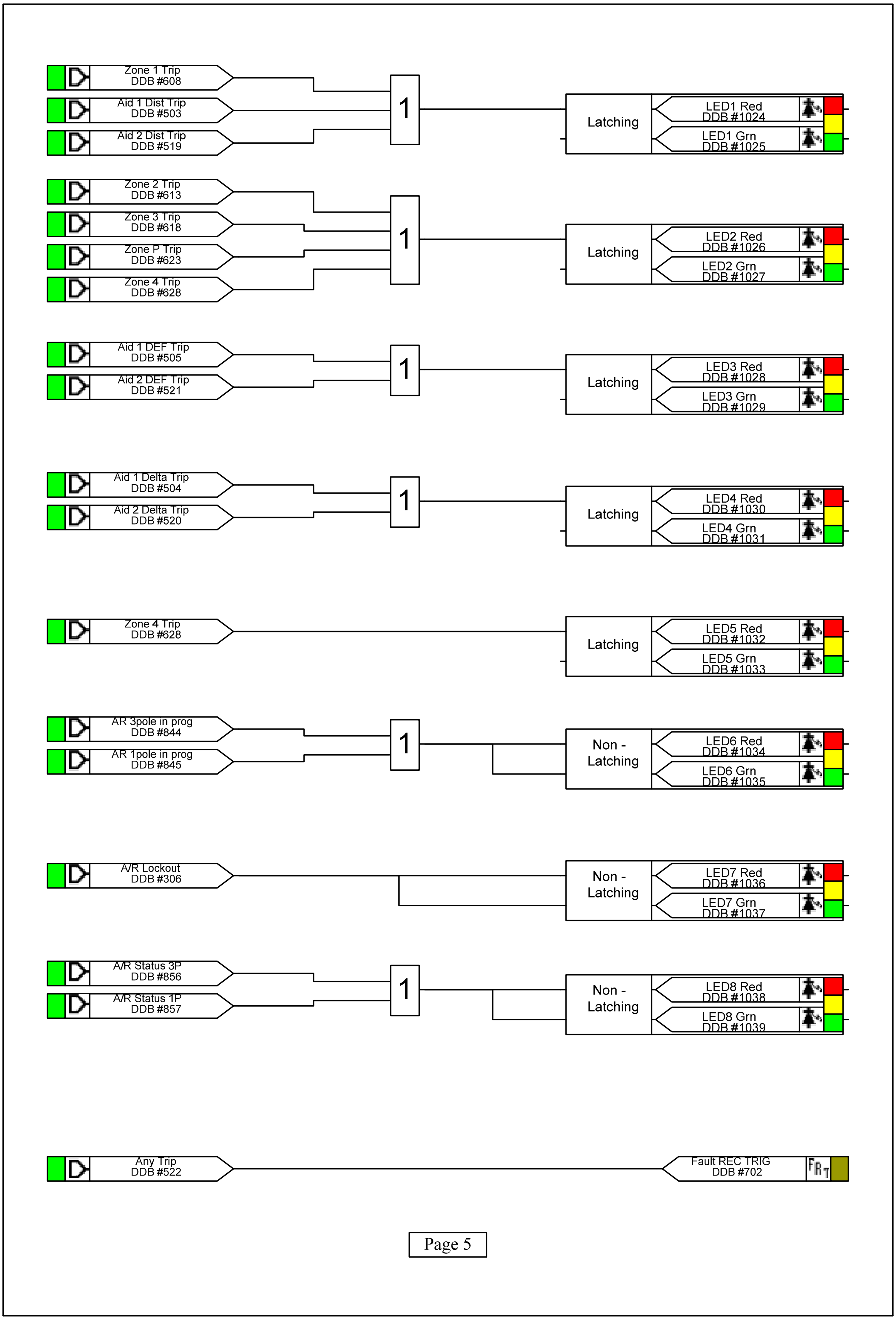
Output Contacts

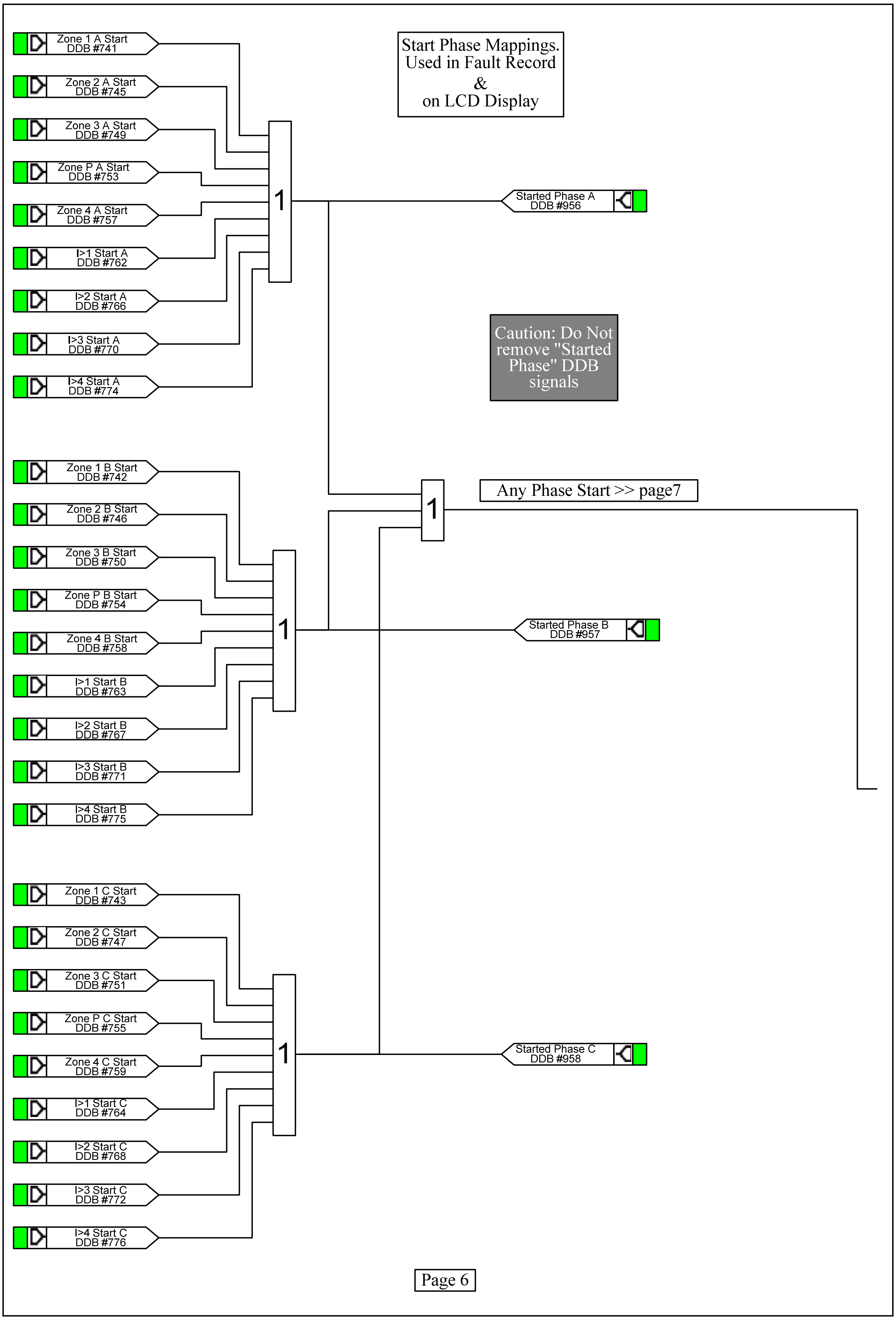

Zone 1 Trip DDB #608
0 Straight 0
Output R1 DDB #000
Any Trip DDB #522
100 Dwell 0
Output R3 DDB #002
IM64 Ch1 Input 1 DDB #096
IM64 Ch2 Input 1 DDB #104
1
0 Straight 0
Output R5 DDB #004
Bfail1 Trip 3ph DDB #834
100 Dwell 0
Output R6 DDB #005
Control Close DDB #839
0 Straight 0
Output R7 DDB #006
Control Trip DDB #838
0 Straight 0
Output R8 DDB #007
Trip Output A DDB #523
100 Dwell 0
Output R9 DDB #008
Trip Outputs are generated by the internal single/three phase trip conversion logic.
Trip Output B DDB #524
100 Dwell 0
Output R10 DDB #009
Trip Output C DDB #525
100 Dwell 0
Output R11 DDB #010
AR 3pole in prog DDB #844
AR 1pole in prog DDB #845
1
0 Straight 0
Output R12 DDB #011
Successful Close DDB #852
0 Straight 0
Output R13 DDB #012
A/R Lockout DDB #306
0 Straight 0
Output R14 DDB #013
A/R Status 3P DDB #856
A/R Status 1P DDB #857
1
0 Straight 0
Output R15 DDB #014
Block AR DDB #581
0 Straight 0
Output R16 DDB #015
Page 2

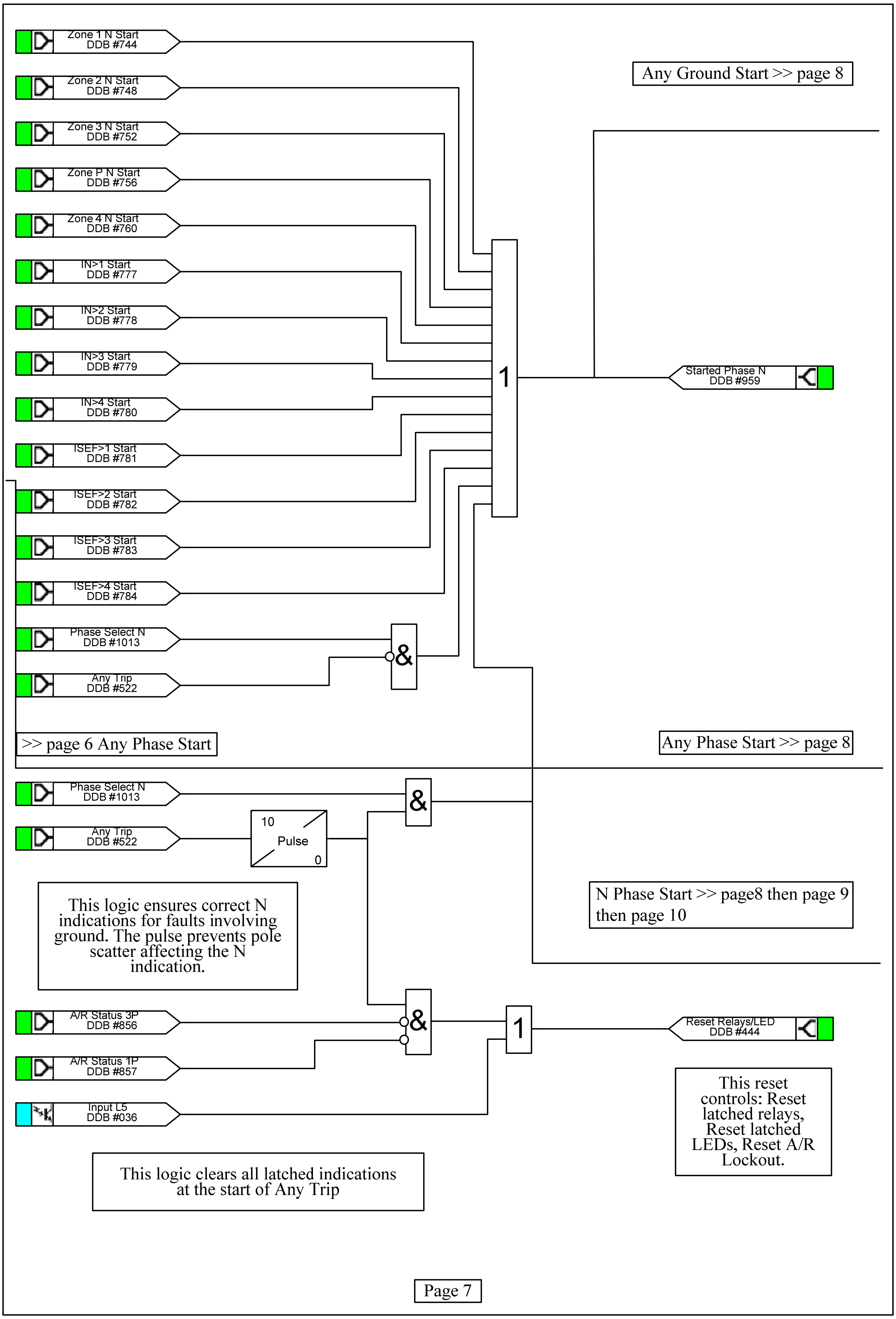

SG-opto Invalid
DDB #288
Prot'n Disabled
DDB #289
Static Test Mode
DDB #290
Test Loopback
DDB #291
Test IM64
DDB #292
VT Fail Alarm
DDB #293
CT Fail Alarm
DDB #294
Power Swing
DDB #297
CB Fail Alarm
DDB #298
CB Monitor Alarm
DDB #299
CB Lockout Alarm
DDB #300
CB Status Alarm
DDB #301
CB Trip Fail
DDB #302
CB Close Fail
DDB #303
Man CB Unhealthy
DDB #304
No C/S Man Close
DDB #305
A/R Lockout
DDB #306
A/R CB Unhealthy
DDB #307
A/R No Checksync
DDB #308
System Split
DDB #309
Signalling Fail
DDB #311
IM64 SchemeFail
DDB #314
IEEE C37.94 Fail
DDB #315
Aid 1 Chan Fail
DDB #317
Aid 2 Chan Fail
DDB #318
F out of Range
DDB #319
InValid Mesg Fmt
DDB #333
Main Prot. Fail
DDB #334
Comms Changed
DDB #337
Battery Fail
DDB #352
Field Volts Fail
DDB #353
Max Prop. Alarm
DDB #338
1
500
Dwell
0
Output R4
DDB #003
General Alarm
Page 3


Trip Output A DDB #523
100 Dwell 0
Output R17 DDB #016
Trip Output B DDB #524
100 Dwell 0
Output R18 DDB #017
Trip Output C DDB #525
100 Dwell 0
Output R19 DDB #018
Zone 1 Trip DDB #608
Aid 1 Dist Trip DDB #503
Aid 2 Dist Trip DDB #519
1
0 Straight 0
Output R20 DDB #019
Zone 2 Trip DDB #613
Zone 3 Trip DDB #618
Zone P Trip DDB #623
Zone 4 Trip DDB #628
1
0 Straight 0
Output R21 DDB #020
Aid 1 DEF Trip DDB #505
Aid 2 DEF Trip DDB #521
1
0 Straight 0
Output R22 DDB #021
Aid 1 Delta Trip DDB #504
Aid 2 Delta Trip DDB #520
1
0 Straight 0
Output R23 DDB #022
Aided 1 Send DDB #498
0 Straight 0
Output R24 DDB #023
IM64 Ch1 Output7 DDB #118
VT Fail Alarm DDB #293
0 Straight 0
Output R27 DDB #026
Power Swing DDB #297
0 Straight 0
Output R28 DDB #027
IM64 Ch1 Input 2 DDB #097
IM64 Ch2 Input 2 DDB #105
1
0 Straight 0
Output R29 DDB #028
IM64 Ch1 Input 3 DDB #098
IM64 Ch2 Input 3 DDB #106
1
0 Straight 0
Output R30 DDB #029
IM64 Ch1 Input 4 DDB #099
IM64 Ch2 Input 4 DDB #107
1
0 Straight 0
Output R31 DDB #030
Page 4

LEDs


Zone 1 Trip
DDB #608
Aid 1 Dist Trip
DDB #503
Aid 2 Dist Trip
DDB #519
1
Latching
LED1 Red
DDB #1024
LED1 Grn
DDB #1025
Zone 2 Trip
DDB #613
Zone 3 Trip
DDB #618
Zone P Trip
DDB #623
Zone 4 Trip
DDB #628
1
Latching
LED2 Red
DDB #1026
LED2 Grn
DDB #1027
Aid 1 DEF Trip
DDB #505
Aid 2 DEF Trip
DDB #521
1
Latching
LED3 Red
DDB #1028
LED3 Grn
DDB #1029
Aid 1 Delta Trip
DDB #504
Aid 2 Delta Trip
DDB #520
1
Latching
LED4 Red
DDB #1030
LED4 Grn
DDB #1031
Zone 4 Trip
DDB #628
Latching
LED5 Red
DDB #1032
LED5 Grn
DDB #1033
AR 3pole in prog
DDB #844
AR 1pole in prog
DDB #845
1
Non - Latching
LED6 Red
DDB #1034
LED6 Grn
DDB #1035
A/R Lockout
DDB #306
Non - Latching
LED7 Red
DDB #1036
LED7 Grn
DDB #1037
A/R Status 3P
DDB #856
A/R Status 1P
DDB #857
1
Non - Latching
LED8 Red
DDB #1038
LED8 Grn
DDB #1039
Any Trip
DDB #522
Fault REC TRIG
DDB #702
Page 5

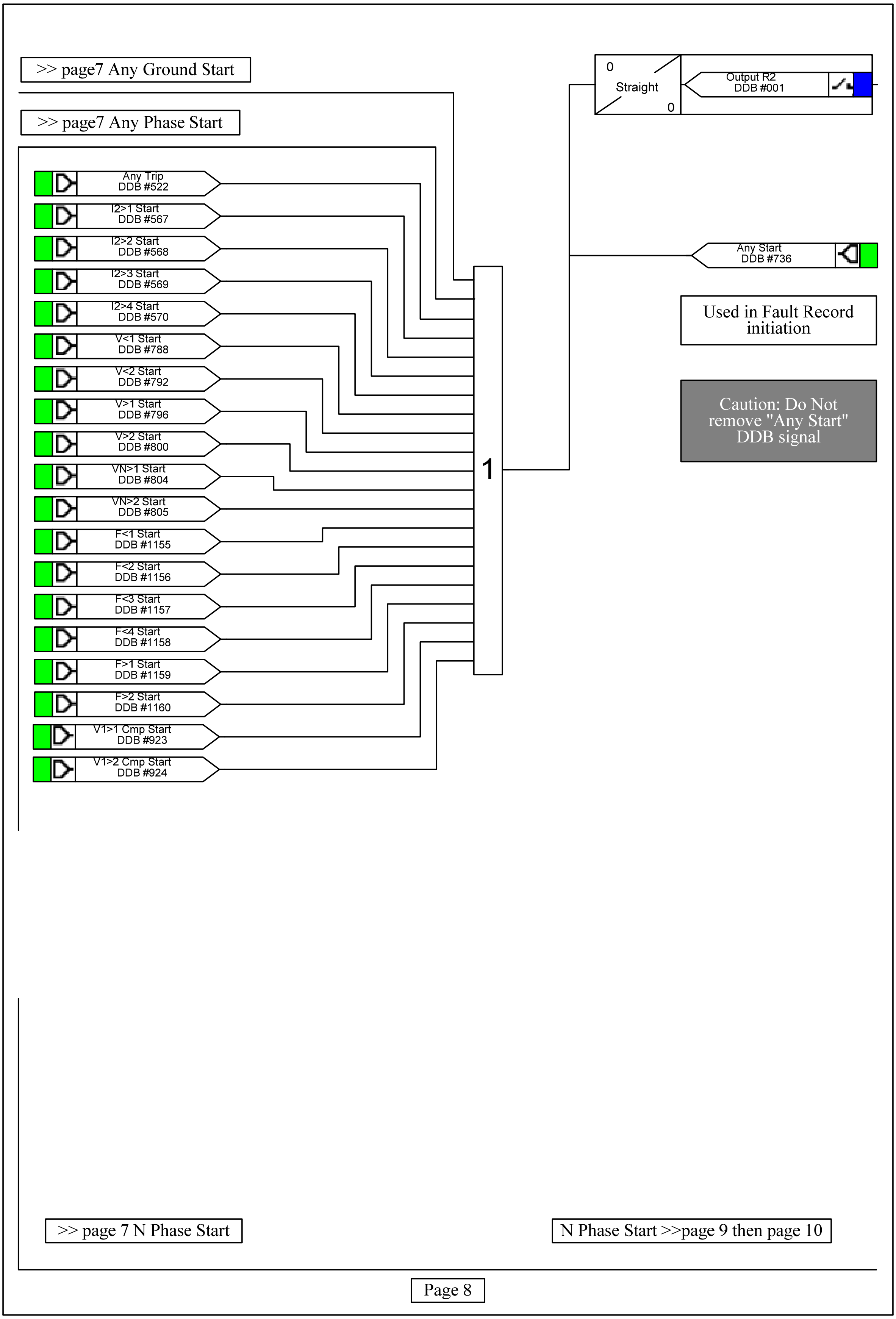

Zone 1 A Start DDB #741
Zone 2 A Start DDB #745
Zone 3 A Start DDB #749
Zone P A Start DDB #753
Zone 4 A Start DDB #757
I>1 Start A DDB #762
I>2 Start A DDB #766
I>3 Start A DDB #770
I>4 Start A DDB #774
1
Started Phase A DDB #956
Start Phase Mappings. Used in Fault Record & on LCD Display
Caution: Do Not remove "Started Phase" DDB signals
Zone 1 B Start DDB #742
Zone 2 B Start DDB #746
Zone 3 B Start DDB #750
Zone P B Start DDB #754
Zone 4 B Start DDB #758
I>1 Start B DDB #763
I>2 Start B DDB #767
I>3 Start B DDB #771
I>4 Start B DDB #775
1
1
Any Phase Start >> page7
Started Phase B DDB #957
Zone 1 C Start DDB #743
Zone 2 C Start DDB #747
Zone 3 C Start DDB #751
Zone P C Start DDB #755
Zone 4 C Start DDB #759
I>1 Start C DDB #764
I>2 Start C DDB #768
I>3 Start C DDB #772
I>4 Start C DDB #776
1
Started Phase C DDB #958
Page 6

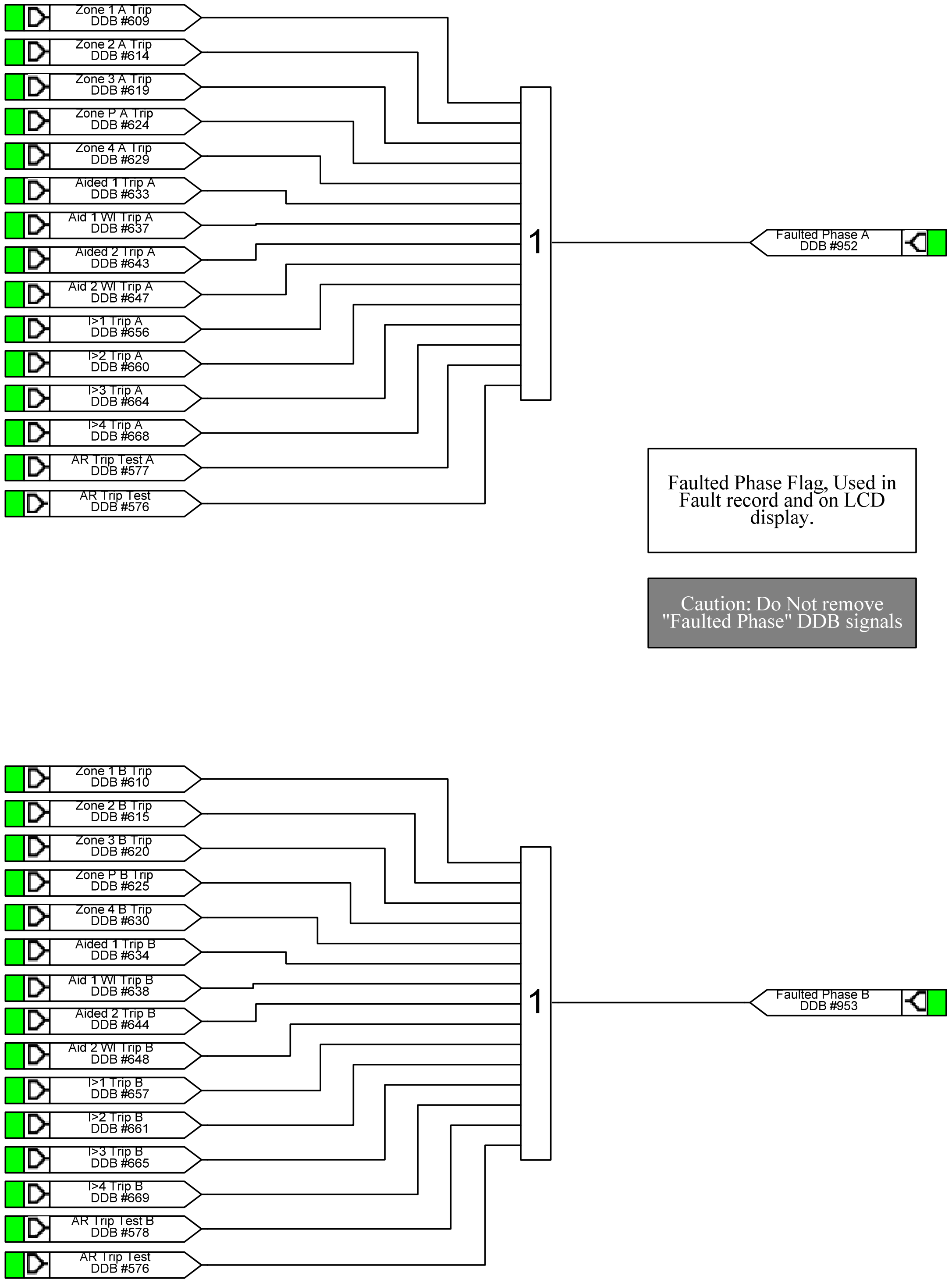

Zone 1 N Start DDB #744
Zone 2 N Start DDB #748
Zone 3 N Start DDB #752
Zone P N Start DDB #756
Zone 4 N Start DDB #760
IN>1 Start DDB #777
IN>2 Start DDB #778
IN>3 Start DDB #779
IN>4 Start DDB #780
ISEF>1 Start DDB #781
ISEF>2 Start DDB #782
ISEF>3 Start DDB #783
ISEF>4 Start DDB #784
Phase Select N DDB #1013
Any Trip DDB #522
&
1
Any Ground Start >> page 8
Started Phase N DDB #959
>> page 6 Any Phase Start
Any Phase Start >> page 8
Phase Select N DDB #1013
Any Trip DDB #522
10
Pulse
0
&
N Phase Start >> page8 then page 9 then page 10
A/R Status 3P DDB #856
A/R Status 1P DDB #857
Input L5 DDB #036
&
1
Reset Relays/LED DDB #444
Page 7

This logic ensures correct N indications for faults involving ground. The pulse prevents pole scatter affecting the N indication.

This logic clears all latched indications at the start of Any Trip

This reset controls: Reset latched relays, Reset latched LEDs, Reset A/R Lockout.


>> page7 Any Ground Start
>> page7 Any Phase Start
Any Trip DDB #522
I2>1 Start DDB #567
I2>2 Start DDB #568
I2>3 Start DDB #569
I2>4 Start DDB #570
V<1 Start DDB #788
V<2 Start DDB #792
V>1 Start DDB #796
V>2 Start DDB #800
VN>1 Start DDB #804
VN>2 Start DDB #805
F<1 Start DDB #1155
F<2 Start DDB #1156
F<3 Start DDB #1157
F<4 Start DDB #1158
F>1 Start DDB #1159
F>2 Start DDB #1160
V1>1 Cmp Start DDB #923
V1>2 Cmp Start DDB #924
1
0
Straight
0
Output R2 DDB #001
Any Start DDB #736
Used in Fault Record initiation
Caution: Do Not remove "Any Start" DDB signal
>> page 7 N Phase Start
N Phase Start >>page 9 then page 10
Page 8


Zone 1 A Trip DDB #609
Zone 2 A Trip DDB #614
Zone 3 A Trip DDB #619
Zone P A Trip DDB #624
Zone 4 A Trip DDB #629
Aided 1 Trip A DDB #633
Aid 1 WI Trip A DDB #637
Aided 2 Trip A DDB #643
Aid 2 WI Trip A DDB #647
I>1 Trip A DDB #656
I>2 Trip A DDB #660
I>3 Trip A DDB #664
I>4 Trip A DDB #668
AR Trip Test A DDB #577
AR Trip Test DDB #576
1
Faulted Phase A DDB #952
Zone 1 B Trip DDB #610
Zone 2 B Trip DDB #615
Zone 3 B Trip DDB #620
Zone P B Trip DDB #625
Zone 4 B Trip DDB #630
Aided 1 Trip B DDB #634
Aid 1 WI Trip B DDB #638
Aided 2 Trip B DDB #644
Aid 2 WI Trip B DDB #648
I>1 Trip B DDB #657
I>2 Trip B DDB #661
I>3 Trip B DDB #665
I>4 Trip B DDB #669
AR Trip Test B DDB #578
AR Trip Test DDB #576
1
Faulted Phase B DDB #953

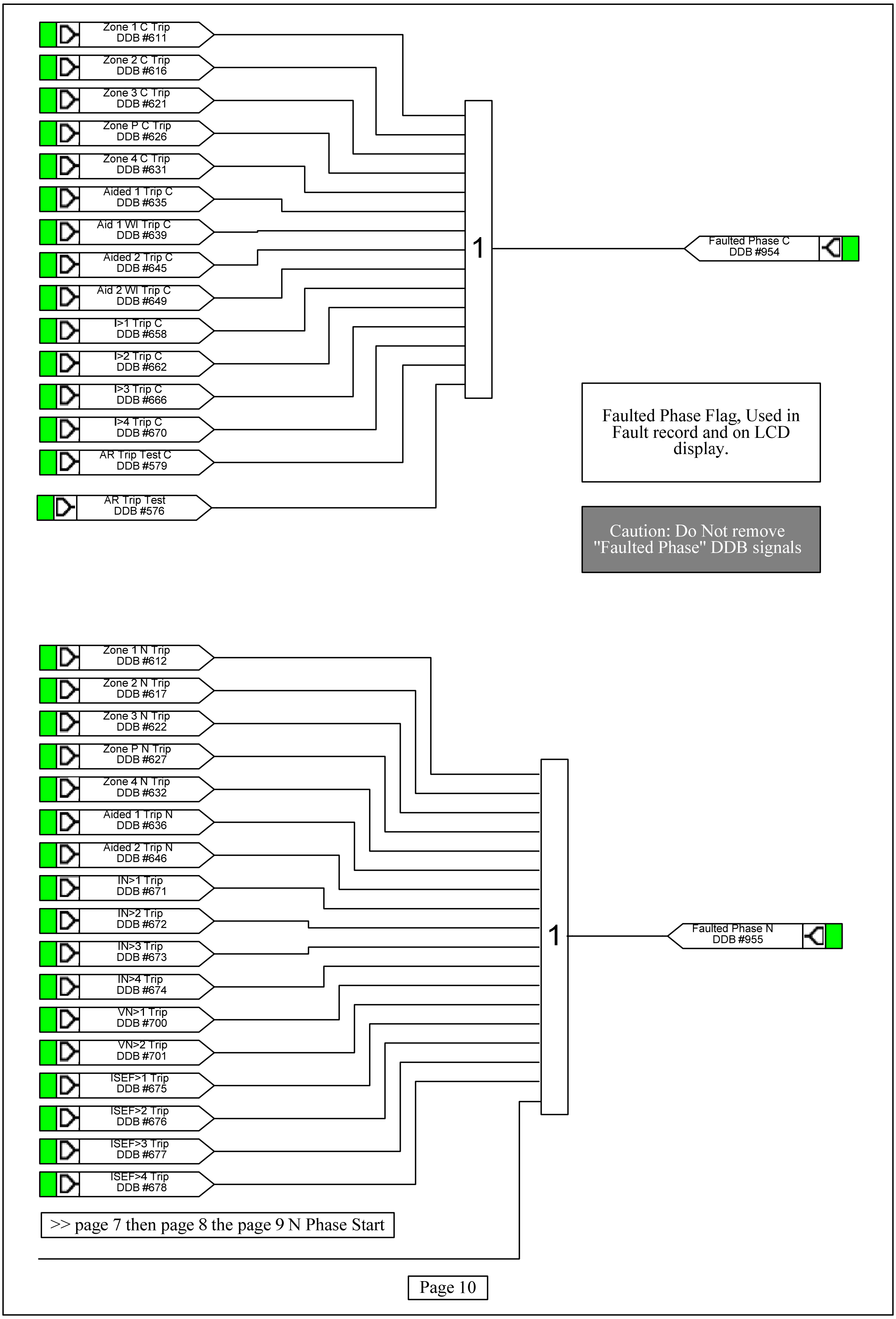
Faulted Phase Flag, Used in Fault record and on LCD display.

Caution: Do Not remove "Faulted Phase" DDB signals

>> page 7 then page 8 N Phase Start

N Phase Start >> page 10

Page 9

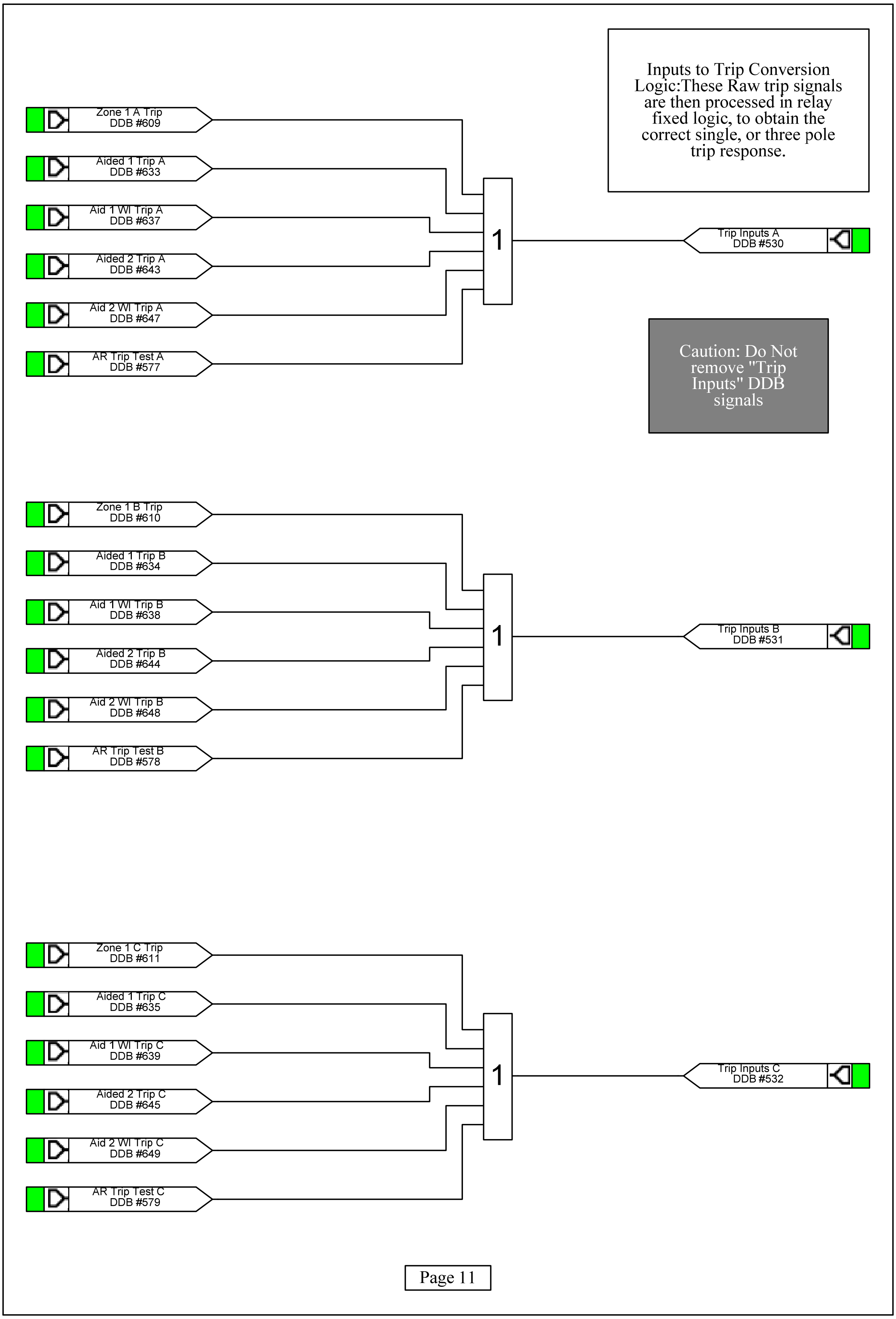

Zone 1 C Trip DDB #611
Zone 2 C Trip DDB #616
Zone 3 C Trip DDB #621
Zone P C Trip DDB #626
Zone 4 C Trip DDB #631
Aided 1 Trip C DDB #635
Aid 1 WI Trip C DDB #639
Aided 2 Trip C DDB #645
Aid 2 WI Trip C DDB #649
I>1 Trip C DDB #658
I>2 Trip C DDB #662
I>3 Trip C DDB #666
I>4 Trip C DDB #670
AR Trip Test C DDB #579
AR Trip Test DDB #576
1
Faulted Phase C DDB #954
Zone 1 N Trip DDB #612
Zone 2 N Trip DDB #617
Zone 3 N Trip DDB #622
Zone P N Trip DDB #627
Zone 4 N Trip DDB #632
Aided 1 Trip N DDB #636
Aided 2 Trip N DDB #646
IN>1 Trip DDB #671
IN>2 Trip DDB #672
IN>3 Trip DDB #673
IN>4 Trip DDB #674
VN>1 Trip DDB #700
VN>2 Trip DDB #701
ISEF>1 Trip DDB #675
ISEF>2 Trip DDB #676
ISEF>3 Trip DDB #677
ISEF>4 Trip DDB #678
1
Faulted Phase N DDB #955

Faulted Phase Flag, Used in Fault record and on LCD display.

Caution: Do Not remove "Faulted Phase" DDB signals

>> page 7 then page 8 the page 9 N Phase Start

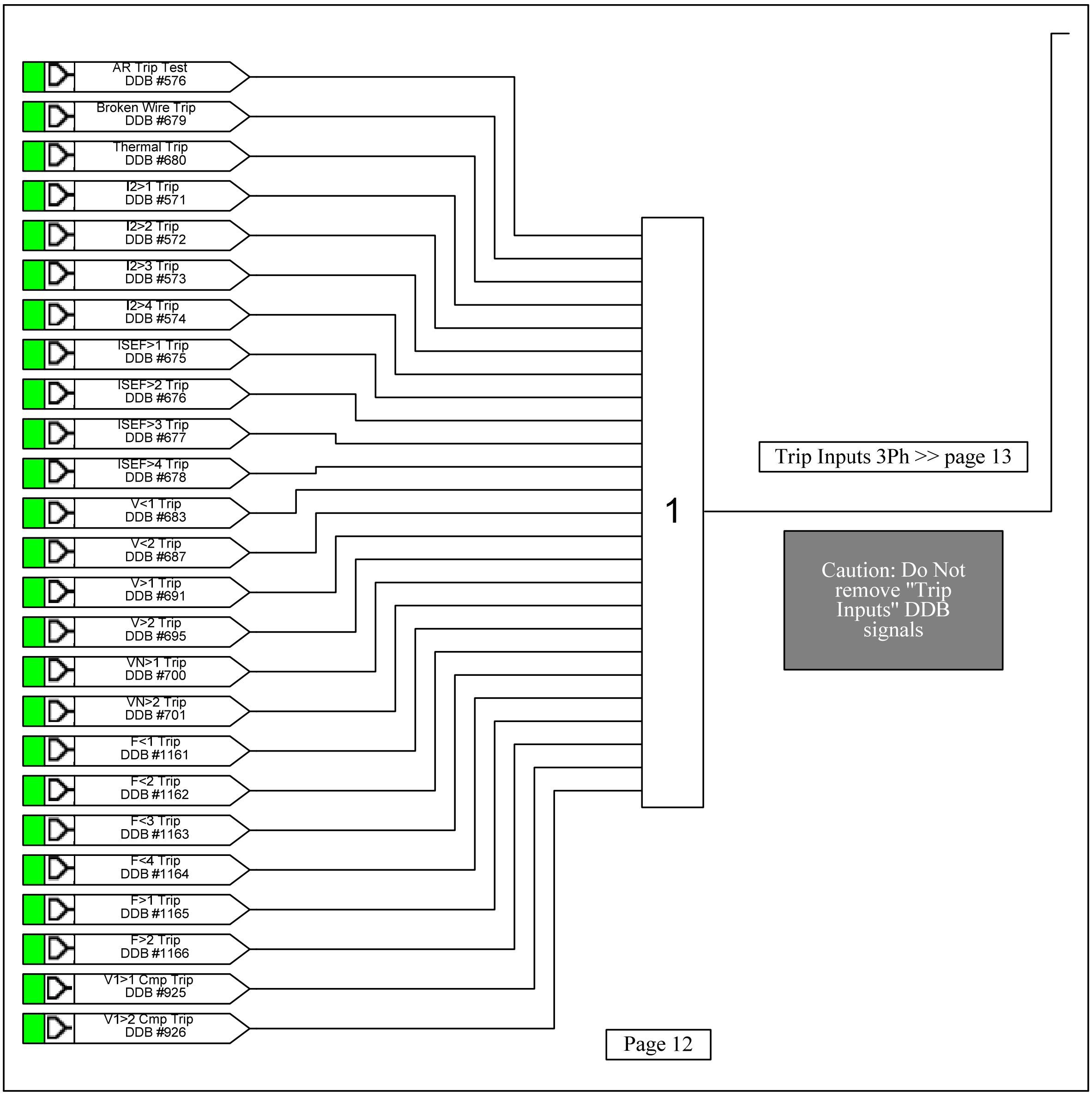
Page 10

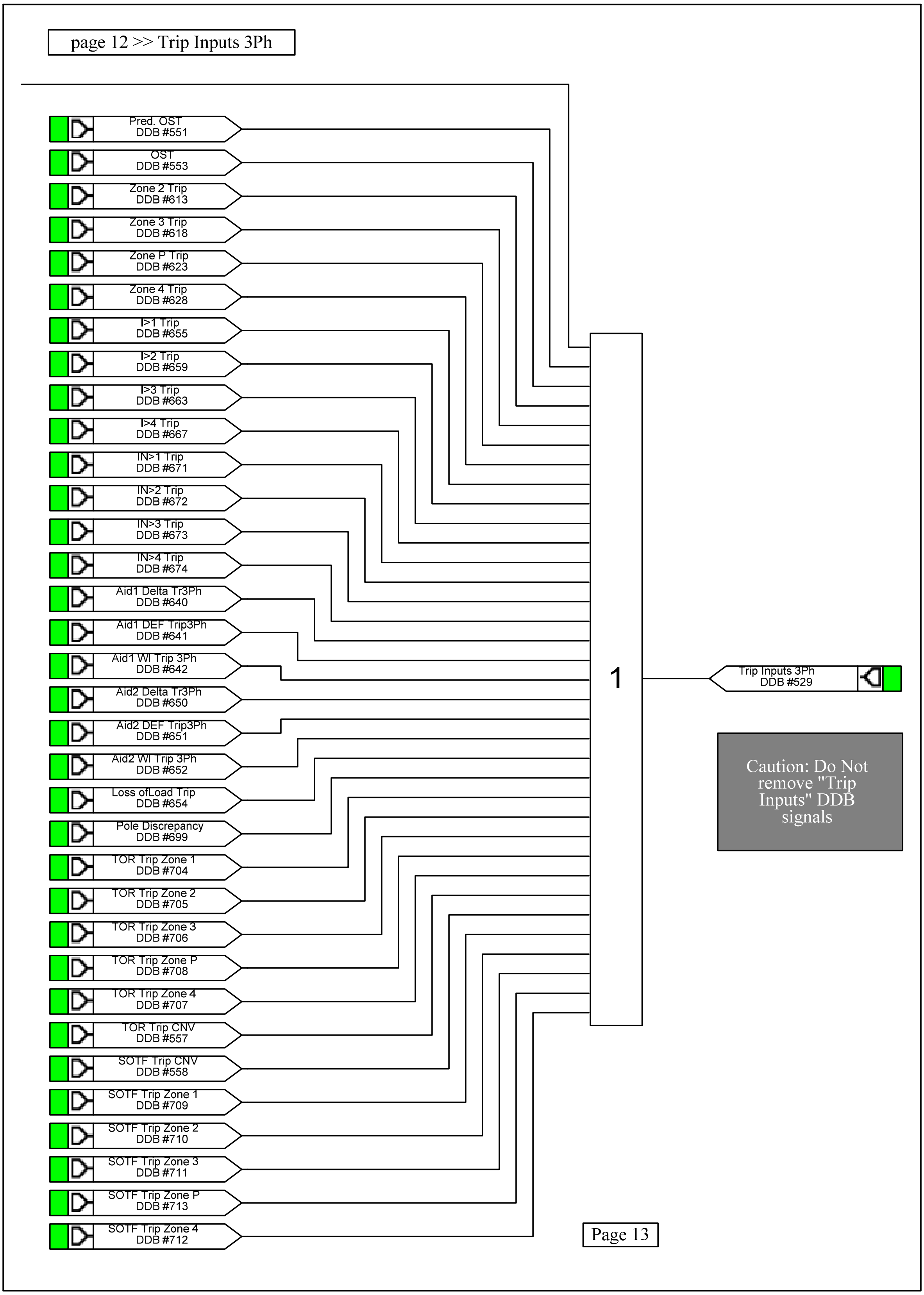


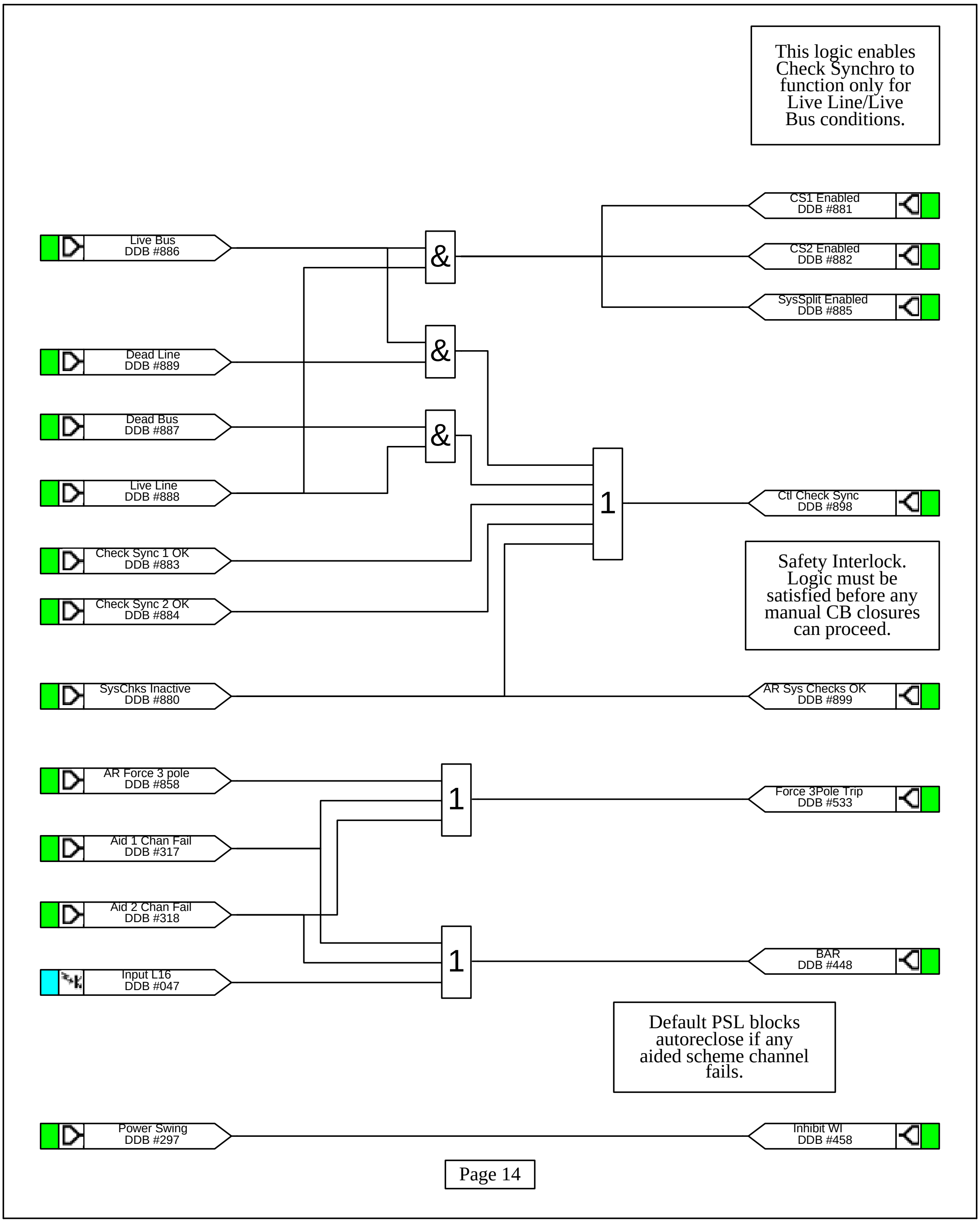
Inputs to Trip Conversion Logic:These Raw trip signals are then processed in relay fixed logic, to obtain the correct single, or three pole trip response.

Caution: Do Not remove "Trip Inputs" DDB signals

Zone 1 A Trip DDB #609
Aided 1 Trip A DDB #633
Aid 1 WI Trip A DDB #637
Aided 2 Trip A DDB #643
Aid 2 WI Trip A DDB #647
AR Trip Test A DDB #577
1
Trip Inputs A DDB #530
Zone 1 B Trip DDB #610
Aided 1 Trip B DDB #634
Aid 1 WI Trip B DDB #638
Aided 2 Trip B DDB #644
Aid 2 WI Trip B DDB #648
AR Trip Test B DDB #578
1
Trip Inputs B DDB #531
Zone 1 C Trip DDB #611
Aided 1 Trip C DDB #635
Aid 1 WI Trip C DDB #639
Aided 2 Trip C DDB #645
Aid 2 WI Trip C DDB #649
AR Trip Test C DDB #579
1
Trip Inputs C DDB #532
Page 11

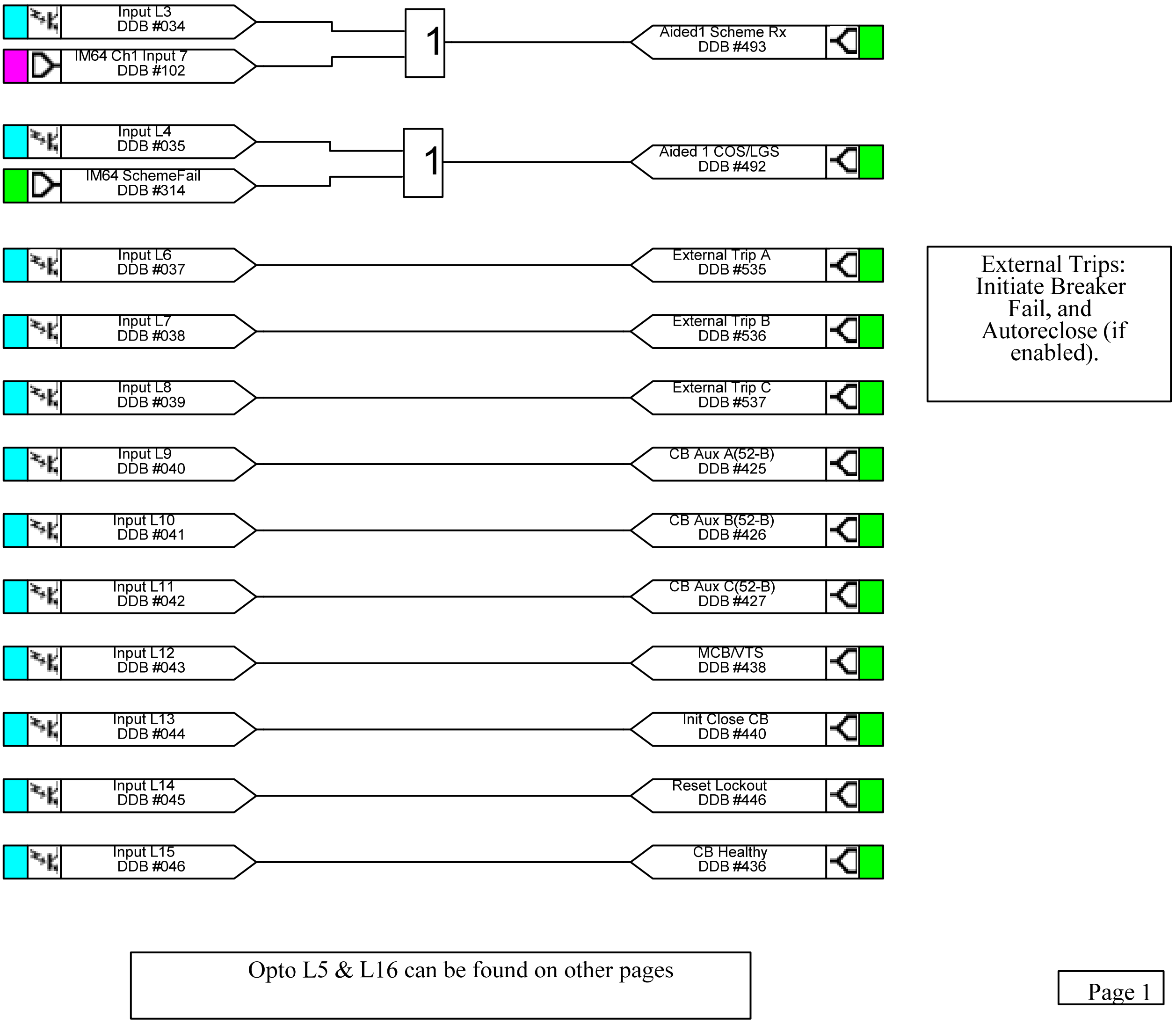

AR Trip Test
DDB #576
Broken Wire Trip
DDB #679
Thermal Trip
DDB #680
I2>1 Trip
DDB #571
I2>2 Trip
DDB #572
I2>3 Trip
DDB #573
I2>4 Trip
DDB #574
ISEF>1 Trip
DDB #675
ISEF>2 Trip
DDB #676
ISEF>3 Trip
DDB #677
ISEF>4 Trip
DDB #678
V<1 Trip
DDB #683
V<2 Trip
DDB #687
V>1 Trip
DDB #691
V>2 Trip
DDB #695
VN>1 Trip
DDB #700
VN>2 Trip
DDB #701
F<1 Trip
DDB #1161
F<2 Trip
DDB #1162
F<3 Trip
DDB #1163
F<4 Trip
DDB #1164
F>1 Trip
DDB #1165
F>2 Trip
DDB #1166
V1>1 Cmp Trip
DDB #925
V1>2 Cmp Trip
DDB #926
1
Trip Inputs 3Ph >> page 13
Caution: Do Not remove "Trip Inputs" DDB signals
Page 12


page 12 >> Trip Inputs 3Ph
Pred. OST DDB #551
OST DDB #553
Zone 2 Trip DDB #613
Zone 3 Trip DDB #618
Zone P Trip DDB #623
Zone 4 Trip DDB #628
I>1 Trip DDB #655
I>2 Trip DDB #659
I>3 Trip DDB #663
I>4 Trip DDB #667
IN>1 Trip DDB #671
IN>2 Trip DDB #672
IN>3 Trip DDB #673
IN>4 Trip DDB #674
Aid1 Delta Tr3Ph DDB #640
Aid1 DEF Trip3Ph DDB #641
Aid1 WI Trip 3Ph DDB #642
Aid2 Delta Tr3Ph DDB #650
Aid2 DEF Trip3Ph DDB #651
Aid2 WI Trip 3Ph DDB #652
Loss ofLoad Trip DDB #654
Pole Discrepancy DDB #699
TOR Trip Zone 1 DDB #704
TOR Trip Zone 2 DDB #705
TOR Trip Zone 3 DDB #706
TOR Trip Zone P DDB #708
TOR Trip Zone 4 DDB #707
TOR Trip CNV DDB #557
SOTF Trip CNV DDB #558
SOTF Trip Zone 1 DDB #709
SOTF Trip Zone 2 DDB #710
SOTF Trip Zone 3 DDB #711
SOTF Trip Zone P DDB #713
SOTF Trip Zone 4 DDB #712
1
Trip Inputs 3Ph DDB #529
Caution: Do Not remove "Trip Inputs" DDB signals
Page 13


This logic enables Check Synchro to function only for Live Line/Live Bus conditions.
Live Bus DDB #886
Dead Line DDB #889
Dead Bus DDB #887
Live Line DDB #888
Check Sync 1 OK DDB #883
Check Sync 2 OK DDB #884
SysChks Inactive DDB #880
AR Force 3 pole DDB #858
Aid 1 Chan Fail DDB #317
Aid 2 Chan Fail DDB #318
Input L16 DDB #047
Power Swing DDB #297
&
&
&
1
1
1
CS1 Enabled DDB #881
CS2 Enabled DDB #882
SysSplit Enabled DDB #885
Ctl Check Sync DDB #898
Safety Interlock. Logic must be satisfied before any manual CB closures can proceed.
AR Sys Checks OK DDB #899
Force 3Pole Trip DDB #533
BAR DDB #448
Default PSL blocks autoreclose if any aided scheme channel fails.
Inhibit WI DDB #458
Page 14

P443 WITH STANDARD CONTACTS PSL 16 STD + 4 HIGH BREAK RELAYS

Opto Input Mappings

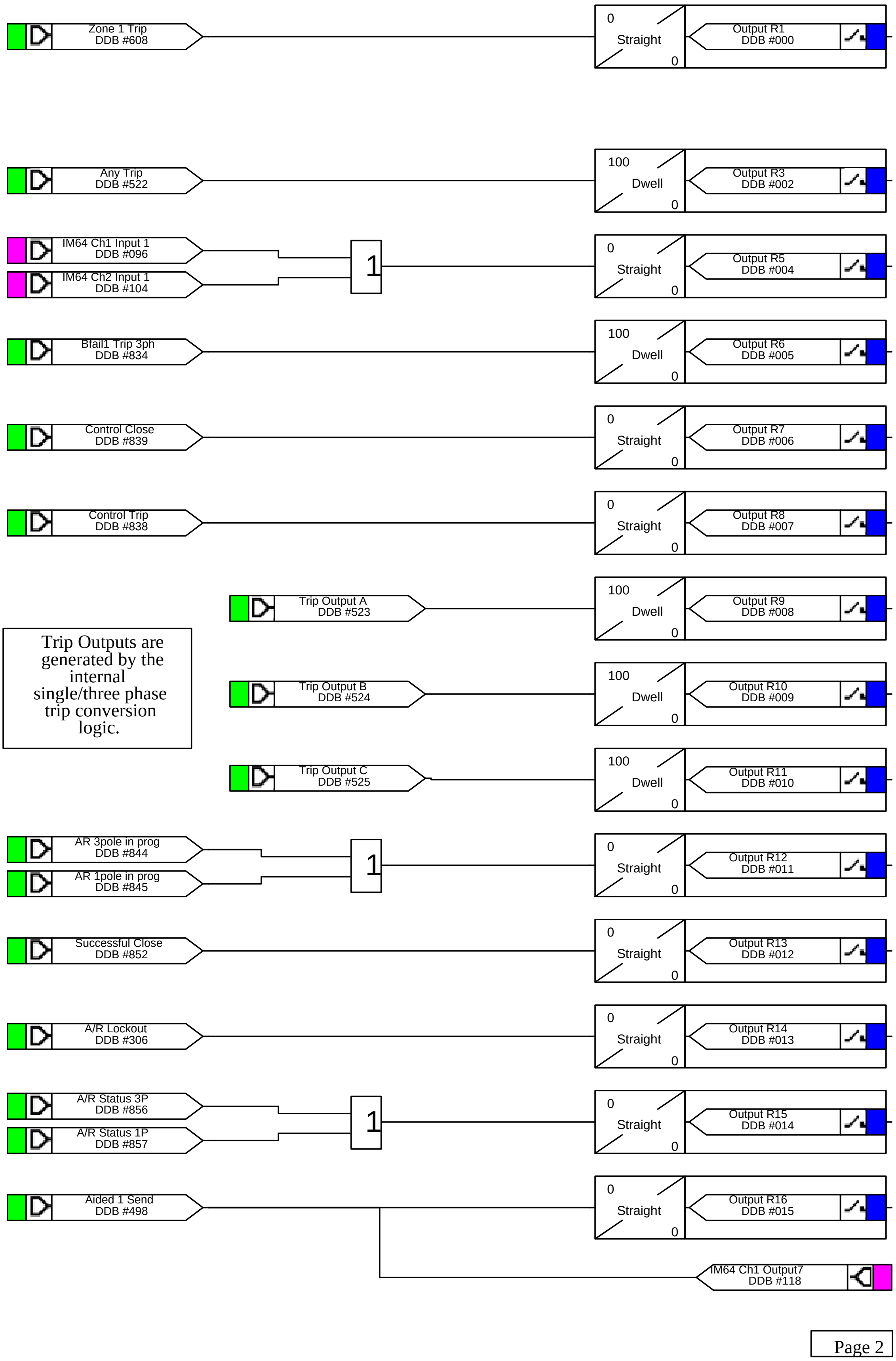

Input L3
DDB #034
IM64 Ch1 Input 7
DDB #102
1
Aided1 Scheme Rx
DDB #493
Input L4
DDB #035
IM64 SchemeFail
DDB #314
1
Aided 1 COS/LGS
DDB #492
Input L6
DDB #037
External Trip A
DDB #535
Input L7
DDB #038
External Trip B
DDB #536
Input L8
DDB #039
External Trip C
DDB #537
Input L9
DDB #040
CB Aux A(52-B)
DDB #425
Input L10
DDB #041
CB Aux B(52-B)
DDB #426
Input L11
DDB #042
CB Aux C(52-B)
DDB #427
Input L12
DDB #043
MCB/VTS
DDB #438
Input L13
DDB #044
Init Close CB
DDB #440
Input L14
DDB #045
Reset Lockout
DDB #446
Input L15
DDB #046
CB Healthy
DDB #436

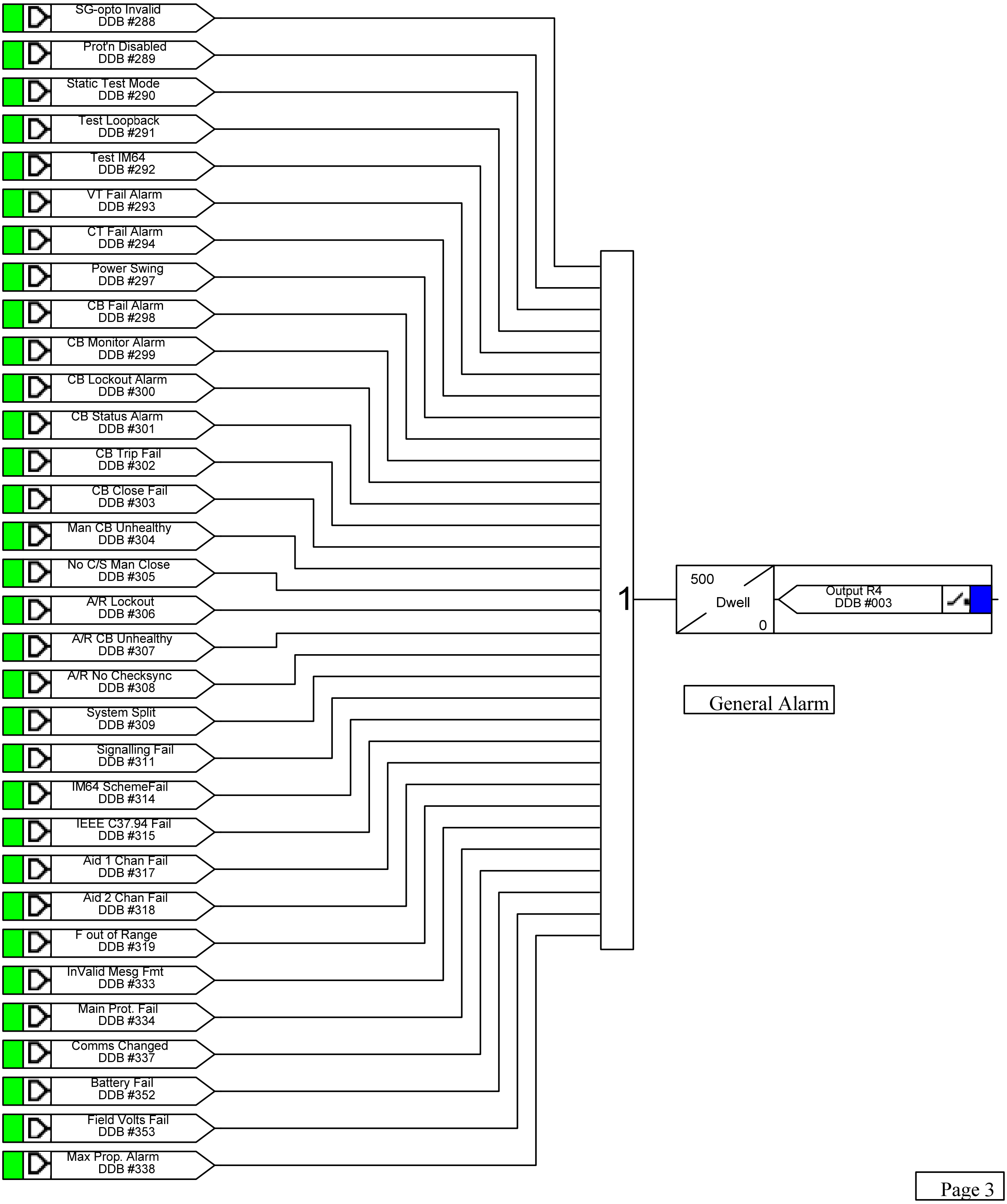
External Trips: Initiate Breaker Fail, and Autoreclose (if enabled).

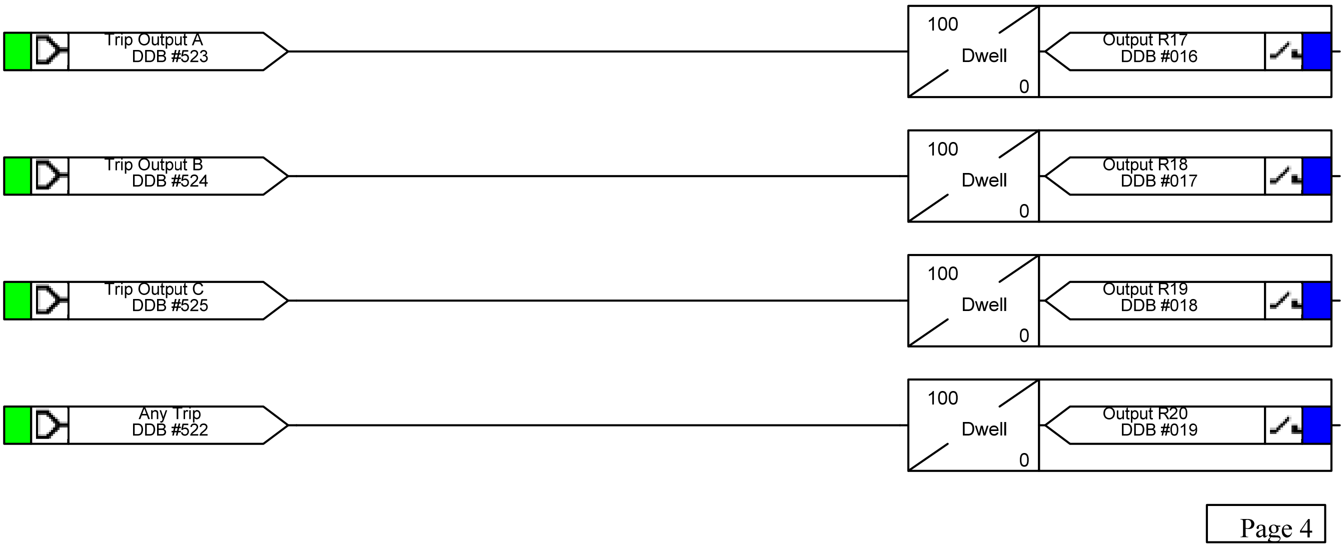
Opto L5 & L16 can be found on other pages

Page 1

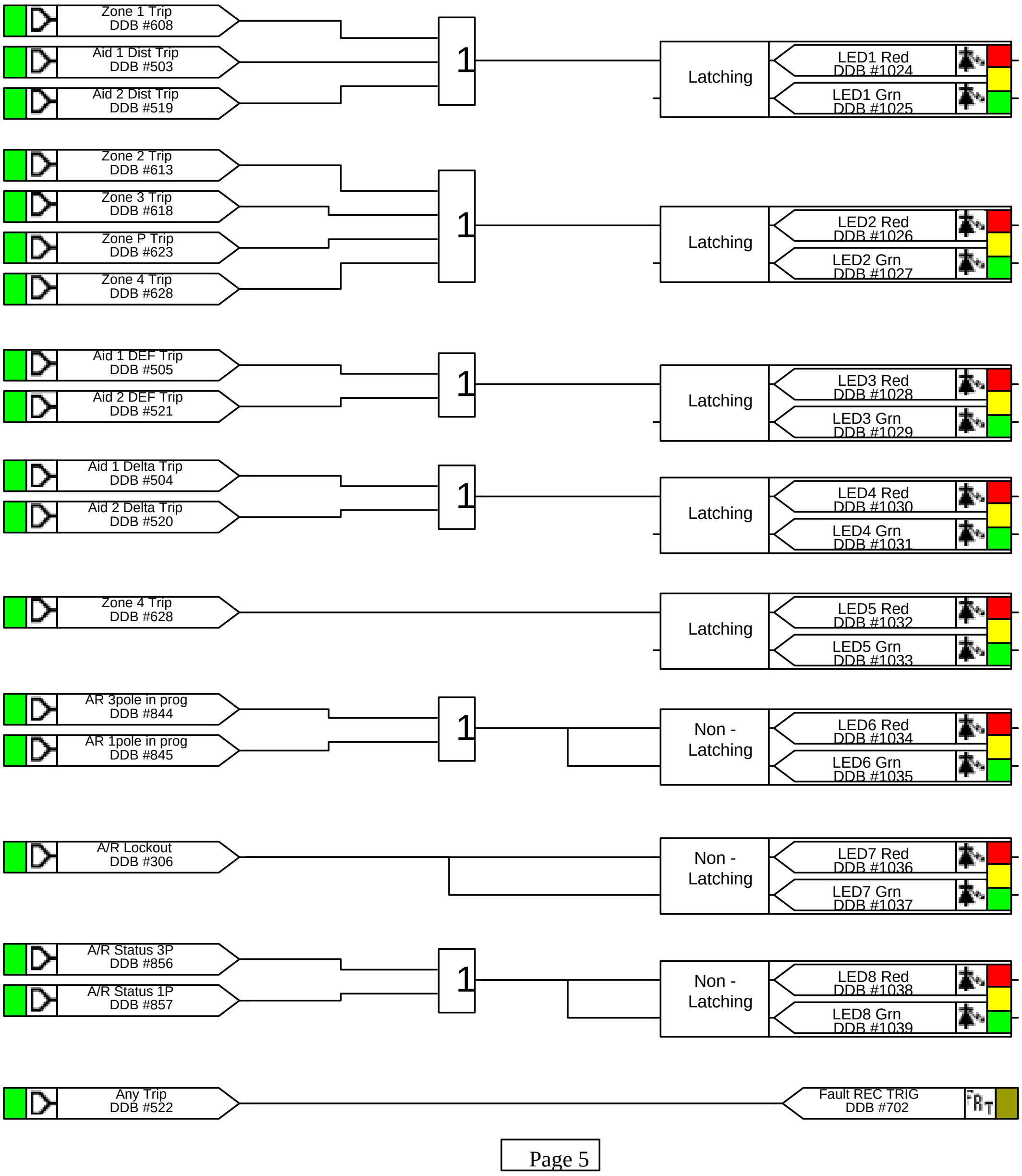
Output Contacts

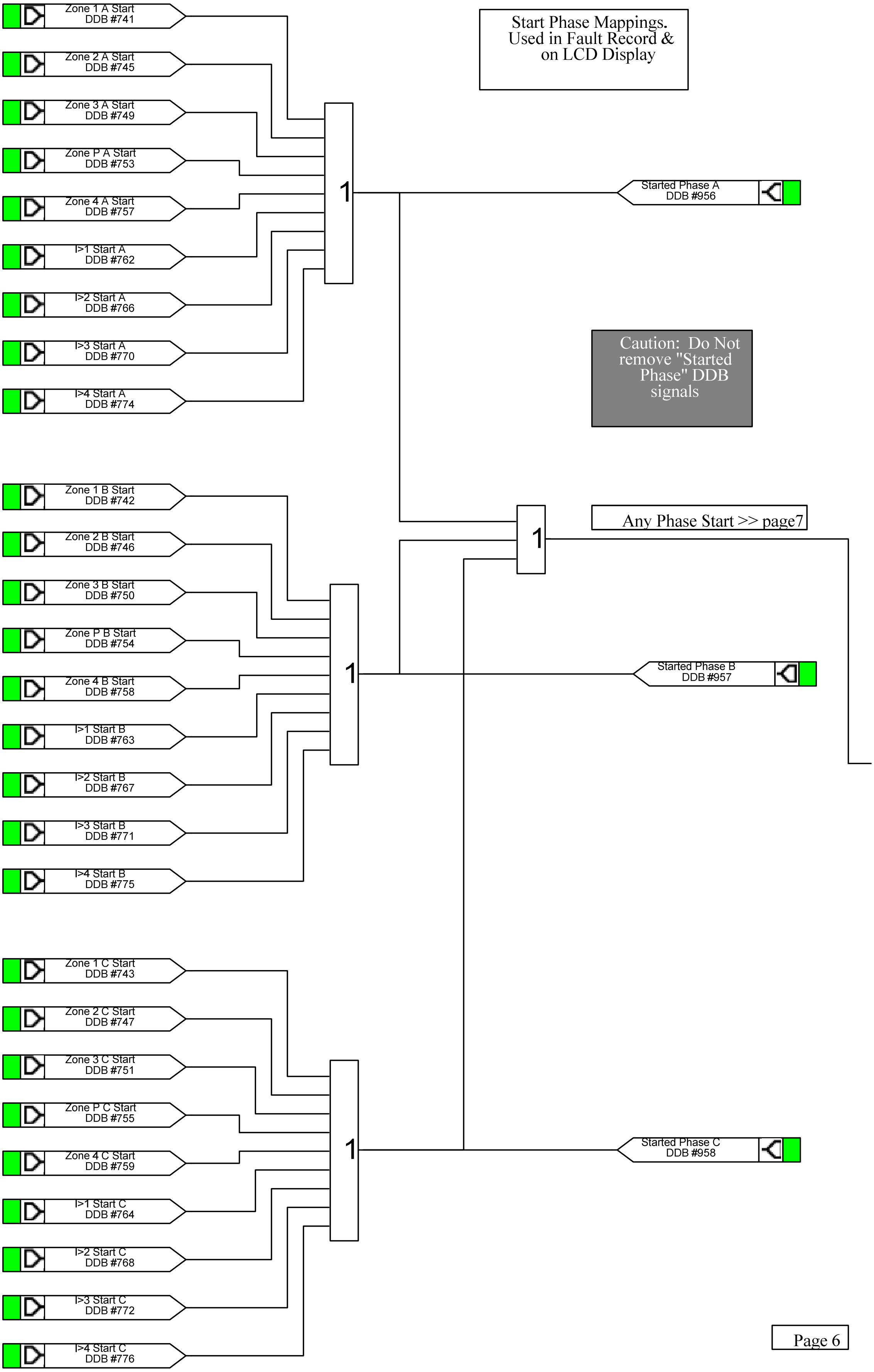

Zone 1 Trip DDB #608
0 Straight 0
Output R1 DDB #000
Any Trip DDB #522
100 Dwell 0
Output R3 DDB #002
IM64 Ch1 Input 1 DDB #096
IM64 Ch2 Input 1 DDB #104
1
0 Straight 0
Output R5 DDB #004
Bfail1 Trip 3ph DDB #834
100 Dwell 0
Output R6 DDB #005
Control Close DDB #839
0 Straight 0
Output R7 DDB #006
Control Trip DDB #838
0 Straight 0
Output R8 DDB #007
Trip Output A DDB #523
100 Dwell 0
Output R9 DDB #008
Trip Outputs are generated by the internal single/three phase trip conversion logic.
Trip Output B DDB #524
100 Dwell 0
Output R10 DDB #009
Trip Output C DDB #525
100 Dwell 0
Output R11 DDB #010
AR 3pole in prog DDB #844
AR 1pole in prog DDB #845
1
0 Straight 0
Output R12 DDB #011
Successful Close DDB #852
0 Straight 0
Output R13 DDB #012
A/R Lockout DDB #306
0 Straight 0
Output R14 DDB #013
A/R Status 3P DDB #856
A/R Status 1P DDB #857
1
0 Straight 0
Output R15 DDB #014
Aided 1 Send DDB #498
0 Straight 0
Output R16 DDB #015
IM64 Ch1 Output7 DDB #118
Page 2

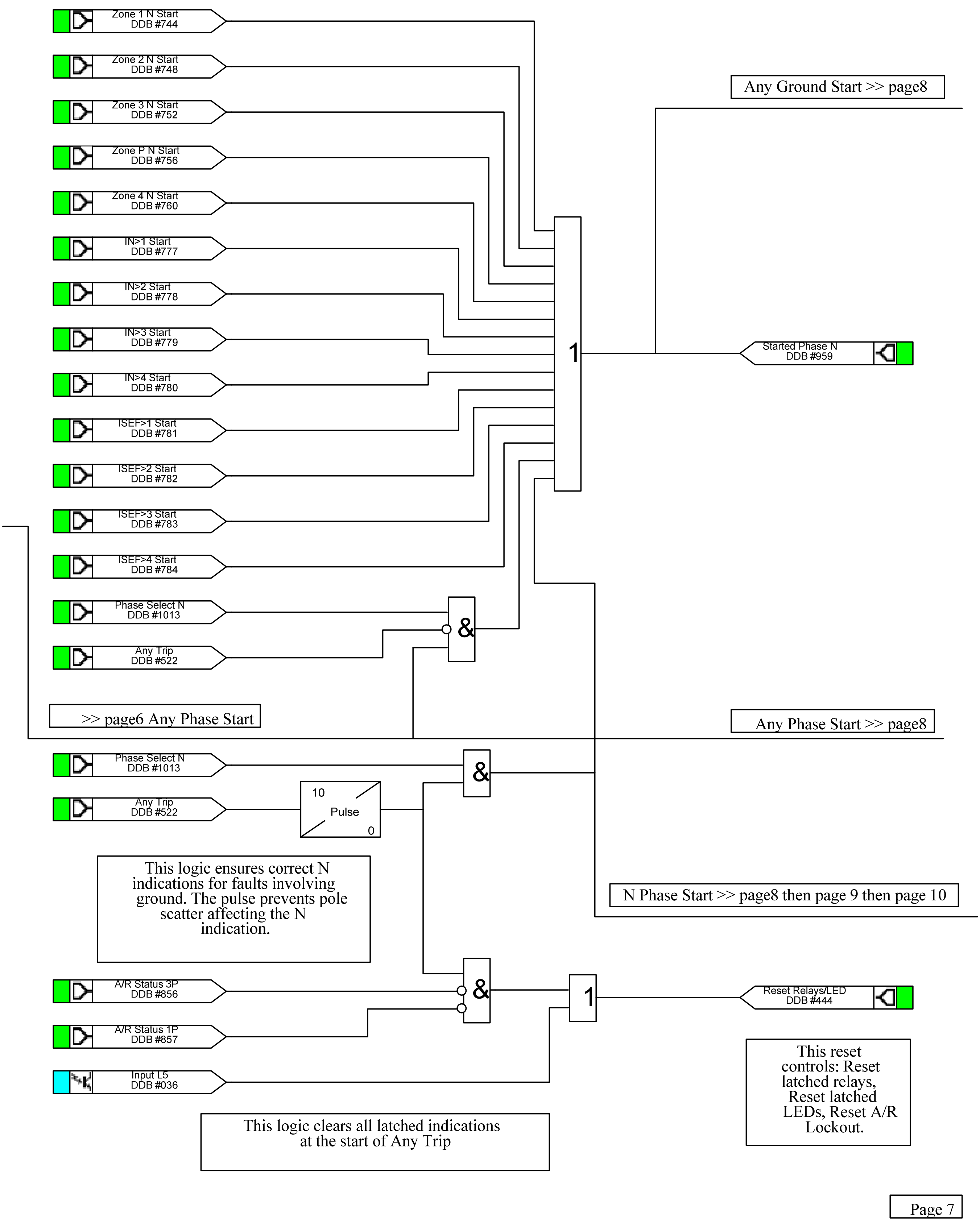

SG-opto Invalid DDB #288
Prot'n Disabled DDB #289
Static Test Mode DDB #290
Test Loopback DDB #291
Test IM64 DDB #292
VT Fail Alarm DDB #293
CT Fail Alarm DDB #294
Power Swing DDB #297
CB Fail Alarm DDB #298
CB Monitor Alarm DDB #299
CB Lockout Alarm DDB #300
CB Status Alarm DDB #301
CB Trip Fail DDB #302
CB Close Fail DDB #303
Man CB Unhealthy DDB #304
No C/S Man Close DDB #305
A/R Lockout DDB #306
A/R CB Unhealthy DDB #307
A/R No Checksync DDB #308
System Split DDB #309
Signalling Fail DDB #311
IM64 SchemeFail DDB #314
IEEE C37.94 Fail DDB #315
Aid 1 Chan Fail DDB #317
Aid 2 Chan Fail DDB #318
F out of Range DDB #319
InValid Mesg Fmt DDB #333
Main Prot. Fail DDB #334
Comms Changed DDB #337
Battery Fail DDB #352
Field Volts Fail DDB #353
Max Prop. Alarm DDB #338
1
500
Dwell
0
Output R4 DDB #003
General Alarm
Page 3


Trip Output A
DDB #523
100
Dwell
0
Output R17
DDB #016
Trip Output B
DDB #524
100
Dwell
0
Output R18
DDB #017
Trip Output C
DDB #525
100
Dwell
0
Output R19
DDB #018
Any Trip
DDB #522
100
Dwell
0
Output R20
DDB #019
Page 4

LEDs


Zone 1 Trip
DDB #608
Aid 1 Dist Trip
DDB #503
Aid 2 Dist Trip
DDB #519
1
Latching
LED1 Red
DDB #1024
LED1 Grn
DDB #1025
Zone 2 Trip
DDB #613
Zone 3 Trip
DDB #618
Zone P Trip
DDB #623
Zone 4 Trip
DDB #628
1
Latching
LED2 Red
DDB #1026
LED2 Grn
DDB #1027
Aid 1 DEF Trip
DDB #505
Aid 2 DEF Trip
DDB #521
1
Latching
LED3 Red
DDB #1028
LED3 Grn
DDB #1029
Aid 1 Delta Trip
DDB #504
Aid 2 Delta Trip
DDB #520
1
Latching
LED4 Red
DDB #1030
LED4 Grn
DDB #1031
Zone 4 Trip
DDB #628
Latching
LED5 Red
DDB #1032
LED5 Grn
DDB #1033
AR 3pole in prog
DDB #844
AR 1pole in prog
DDB #845
1
Non - Latching
LED6 Red
DDB #1034
LED6 Grn
DDB #1035
A/R Lockout
DDB #306
Non - Latching
LED7 Red
DDB #1036
LED7 Grn
DDB #1037
A/R Status 3P
DDB #856
A/R Status 1P
DDB #857
1
Non - Latching
LED8 Red
DDB #1038
LED8 Grn
DDB #1039
Any Trip
DDB #522
Fault REC TRIG
DDB #702
Page 5

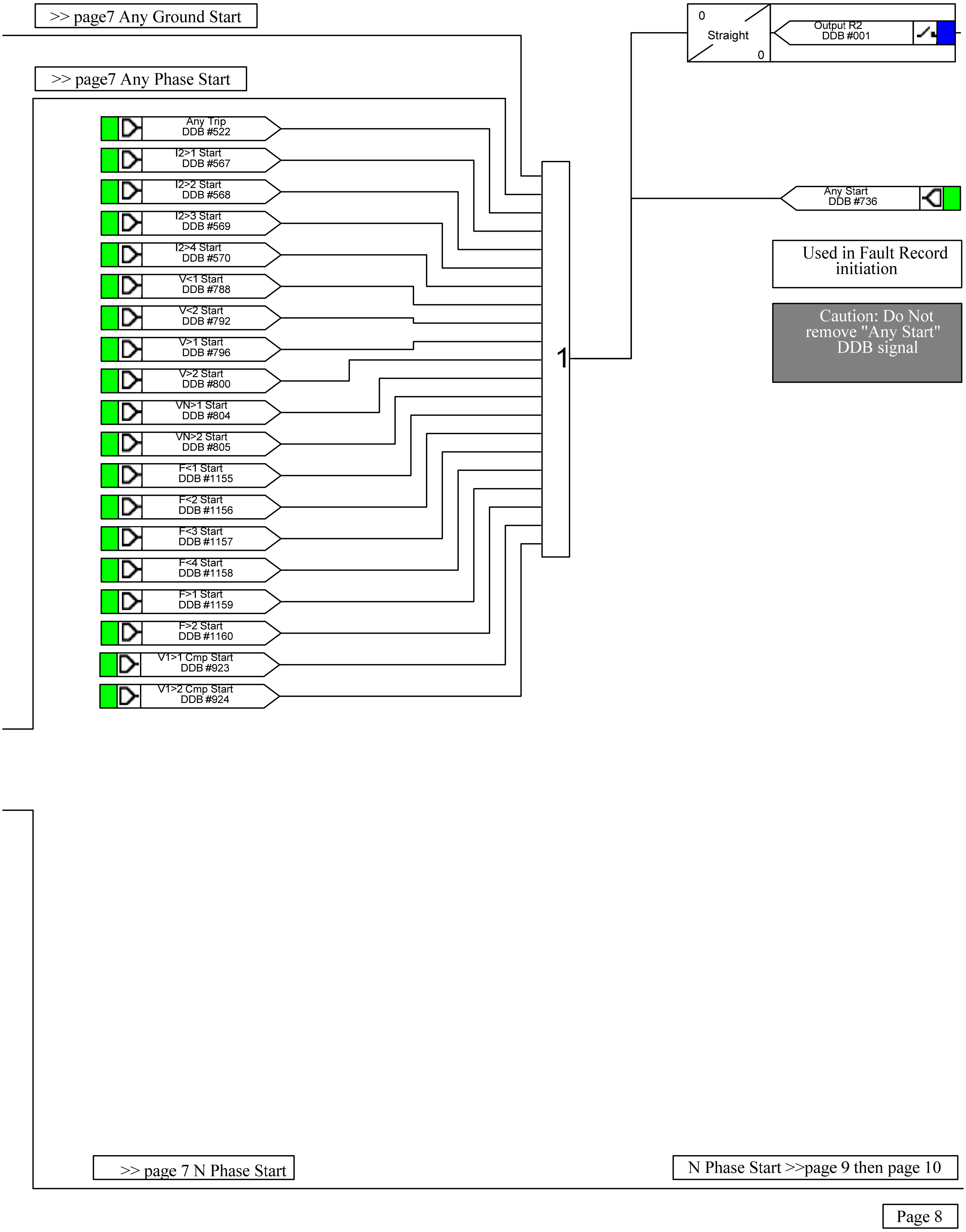

Zone 1 A Start DDB #741
Zone 2 A Start DDB #745
Zone 3 A Start DDB #749
Zone P A Start DDB #753
Zone 4 A Start DDB #757
I>1 Start A DDB #762
I>2 Start A DDB #766
I>3 Start A DDB #770
I>4 Start A DDB #774
1
Started Phase A DDB #956
Start Phase Mappings. Used in Fault Record & on LCD Display
Caution: Do Not remove "Started Phase" DDB signals
Zone 1 B Start DDB #742
Zone 2 B Start DDB #746
Zone 3 B Start DDB #750
Zone P B Start DDB #754
Zone 4 B Start DDB #758
I>1 Start B DDB #763
I>2 Start B DDB #767
I>3 Start B DDB #771
I>4 Start B DDB #775
1
1
Any Phase Start >> page7
Started Phase B DDB #957
Zone 1 C Start DDB #743
Zone 2 C Start DDB #747
Zone 3 C Start DDB #751
Zone P C Start DDB #755
Zone 4 C Start DDB #759
I>1 Start C DDB #764
I>2 Start C DDB #768
I>3 Start C DDB #772
I>4 Start C DDB #776
1
Started Phase C DDB #958
Page 6

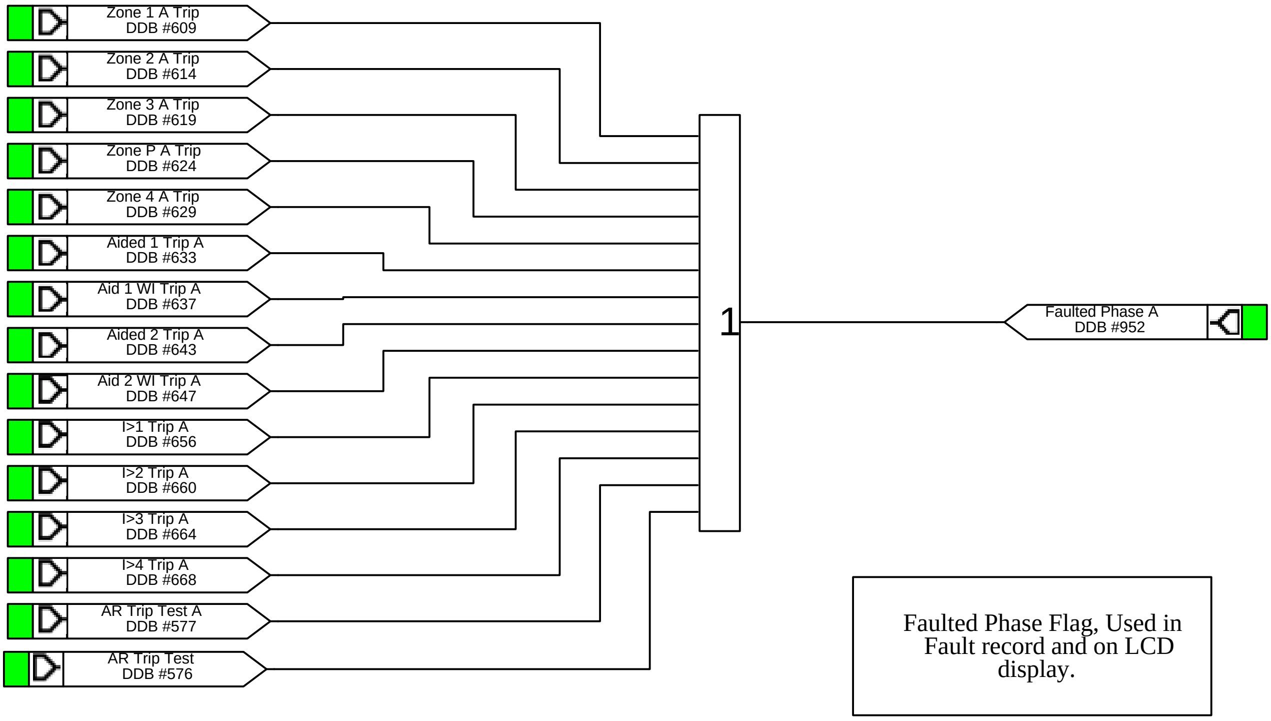

Zone 1 N Start DDB #744
Zone 2 N Start DDB #748
Zone 3 N Start DDB #752
Zone P N Start DDB #756
Zone 4 N Start DDB #760
IN>1 Start DDB #777
IN>2 Start DDB #778
IN>3 Start DDB #779
IN>4 Start DDB #780
ISEF>1 Start DDB #781
ISEF>2 Start DDB #782
ISEF>3 Start DDB #783
ISEF>4 Start DDB #784
Phase Select N DDB #1013
Any Trip DDB #522
Any Ground Start >> page8
1
Started Phase N DDB #959
&
>> page6 Any Phase Start
Any Phase Start >> page8
Phase Select N DDB #1013
Any Trip DDB #522
10
Pulse
0
&
N Phase Start >> page8 then page 9 then page 10
A/R Status 3P DDB #856
A/R Status 1P DDB #857
Input L5 DDB #036
&
1
Reset Relays/LED DDB #444
Page 7

This logic ensures correct N indications for faults involving ground. The pulse prevents pole scatter affecting the N indication.

This reset controls: Reset latched relays, Reset latched LEDs, Reset A/R Lockout.

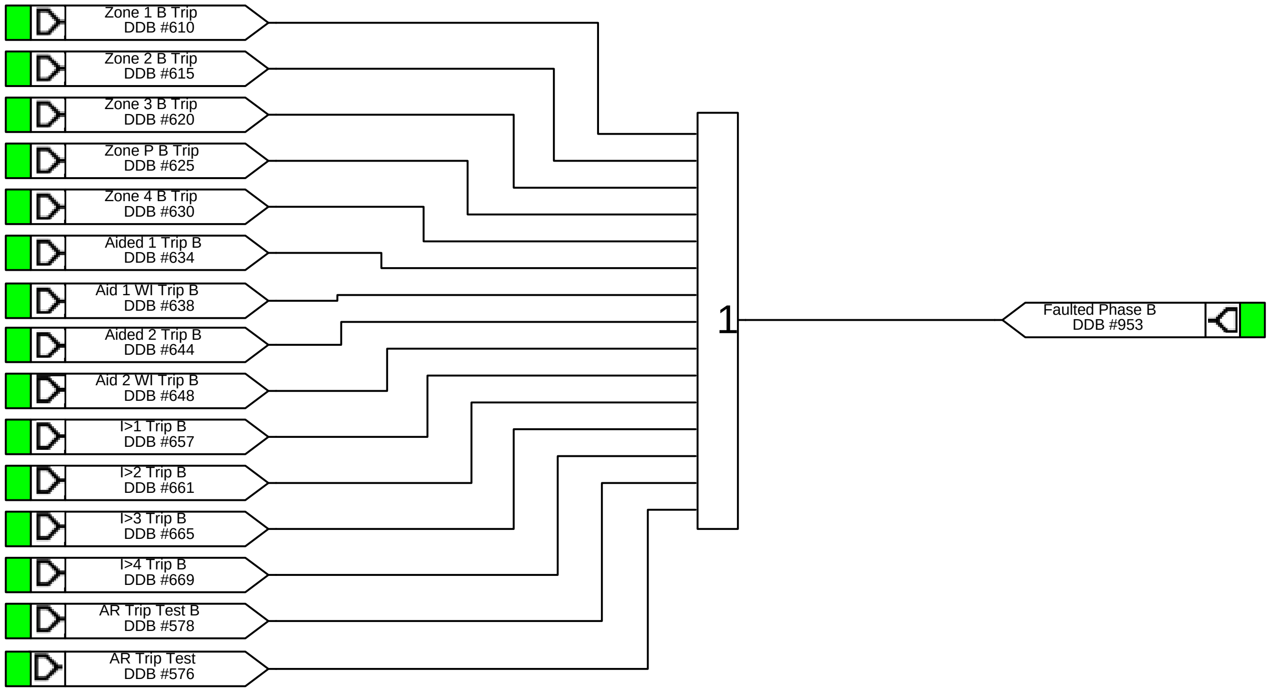
This logic clears all latched indications at the start of Any Trip


>> page7 Any Ground Start
>> page7 Any Phase Start
Any Trip DDB #522
I2>1 Start DDB #567
I2>2 Start DDB #568
I2>3 Start DDB #569
I2>4 Start DDB #570
V<1 Start DDB #788
V<2 Start DDB #792
V>1 Start DDB #796
V>2 Start DDB #800
VN>1 Start DDB #804
VN>2 Start DDB #805
F<1 Start DDB #1155
F<2 Start DDB #1156
F<3 Start DDB #1157
F<4 Start DDB #1158
F>1 Start DDB #1159
F>2 Start DDB #1160
V1>1 Cmp Start DDB #923
V1>2 Cmp Start DDB #924
1
0
Straight
0
Output R2 DDB #001
Any Start DDB #736
Used in Fault Record initiation
Caution: Do Not remove "Any Start" DDB signal
>> page 7 N Phase Start
N Phase Start >>page 9 then page 10
Page 8


Zone 1 A Trip
DDB #609
Zone 2 A Trip
DDB #614
Zone 3 A Trip
DDB #619
Zone P A Trip
DDB #624
Zone 4 A Trip
DDB #629
Aided 1 Trip A
DDB #633
Aid 1 WI Trip A
DDB #637
Aided 2 Trip A
DDB #643
Aid 2 WI Trip A
DDB #647
I>1 Trip A
DDB #656
I>2 Trip A
DDB #660
I>3 Trip A
DDB #664
I>4 Trip A
DDB #668
AR Trip Test A
DDB #577
AR Trip Test
DDB #576
1
Faulted Phase A
DDB #952

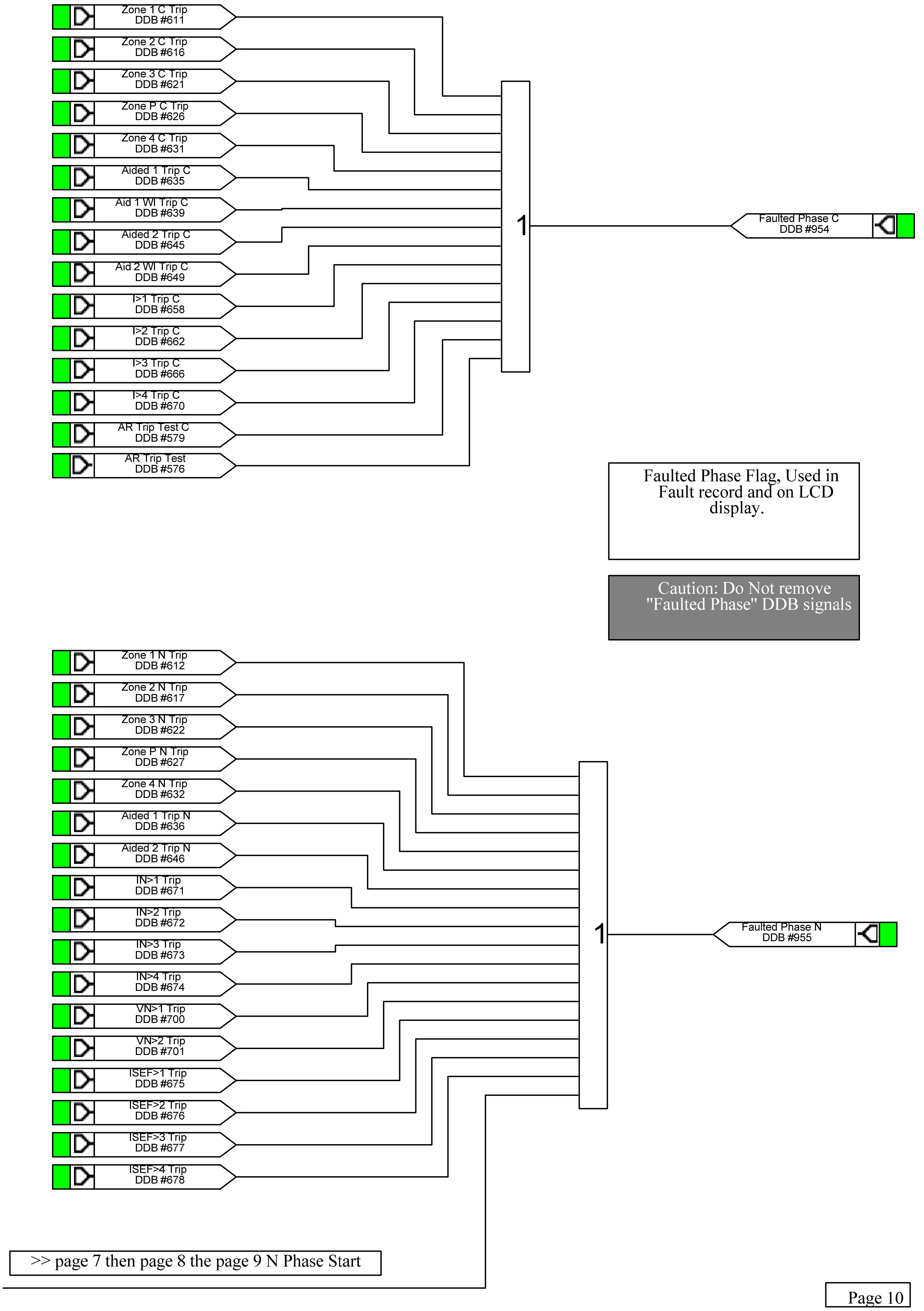
Faulted Phase Flag, Used in Fault record and on LCD display.

Caution: Do Not remove "Faulted Phase" DDB signals


Zone 1 B Trip
DDB #610
Zone 2 B Trip
DDB #615
Zone 3 B Trip
DDB #620
Zone P B Trip
DDB #625
Zone 4 B Trip
DDB #630
Aided 1 Trip B
DDB #634
Aid 1 WI Trip B
DDB #638
Aided 2 Trip B
DDB #644
Aid 2 WI Trip B
DDB #648
I>1 Trip B
DDB #657
I>2 Trip B
DDB #661
I>3 Trip B
DDB #665
I>4 Trip B
DDB #669
AR Trip Test B
DDB #578
AR Trip Test
DDB #576
1
Faulted Phase B
DDB #953

>> page 7 then page 8 N Phase Start

N Phase Start >> page 10

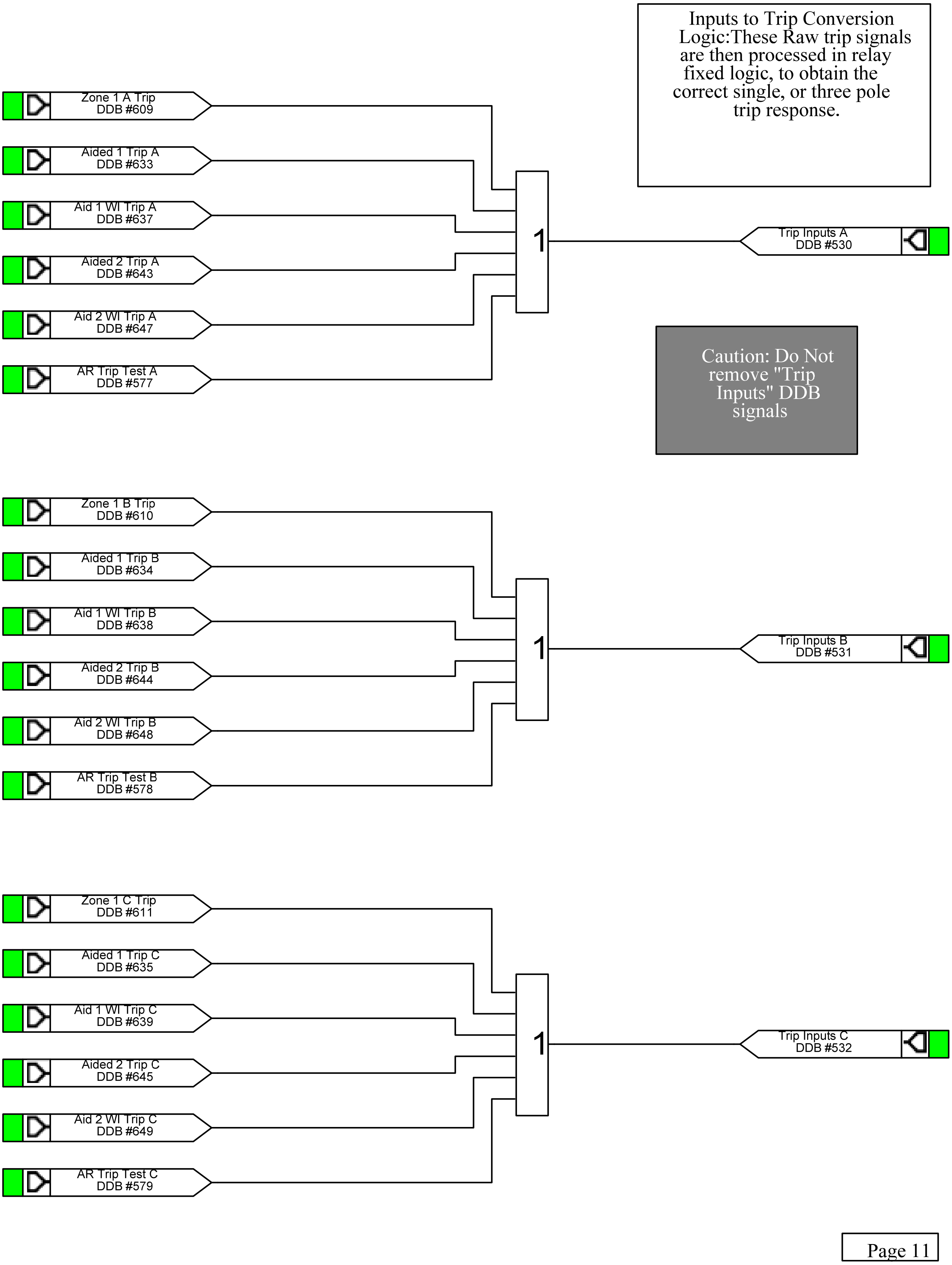

Zone 1 C Trip DDB #611
Zone 2 C Trip DDB #616
Zone 3 C Trip DDB #621
Zone P C Trip DDB #626
Zone 4 C Trip DDB #631
Aided 1 Trip C DDB #635
Aid 1 WI Trip C DDB #639
Aided 2 Trip C DDB #645
Aid 2 WI Trip C DDB #649
I>1 Trip C DDB #658
I>2 Trip C DDB #662
I>3 Trip C DDB #666
I>4 Trip C DDB #670
AR Trip Test C DDB #579
AR Trip Test DDB #576
1
Faulted Phase C DDB #954
Zone 1 N Trip DDB #612
Zone 2 N Trip DDB #617
Zone 3 N Trip DDB #622
Zone P N Trip DDB #627
Zone 4 N Trip DDB #632
Aided 1 Trip N DDB #636
Aided 2 Trip N DDB #646
IN>1 Trip DDB #671
IN>2 Trip DDB #672
IN>3 Trip DDB #673
IN>4 Trip DDB #674
VN>1 Trip DDB #700
VN>2 Trip DDB #701
ISEF>1 Trip DDB #675
ISEF>2 Trip DDB #676
ISEF>3 Trip DDB #677
ISEF>4 Trip DDB #678
1
Faulted Phase N DDB #955

Faulted Phase Flag, Used in Fault record and on LCD display.

Caution: Do Not remove "Faulted Phase" DDB signals

>> page 7 then page 8 the page 9 N Phase Start

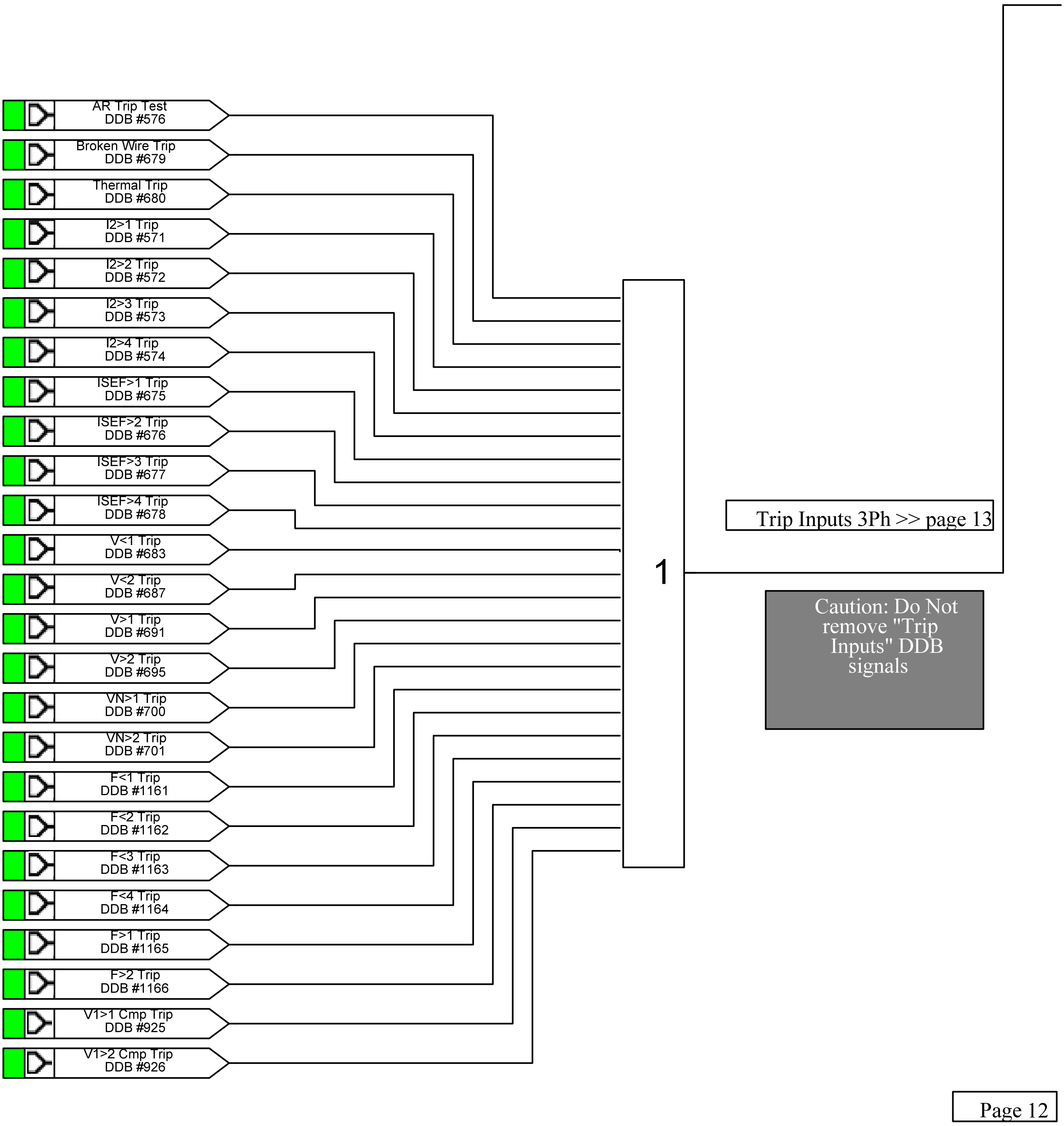
Page 10

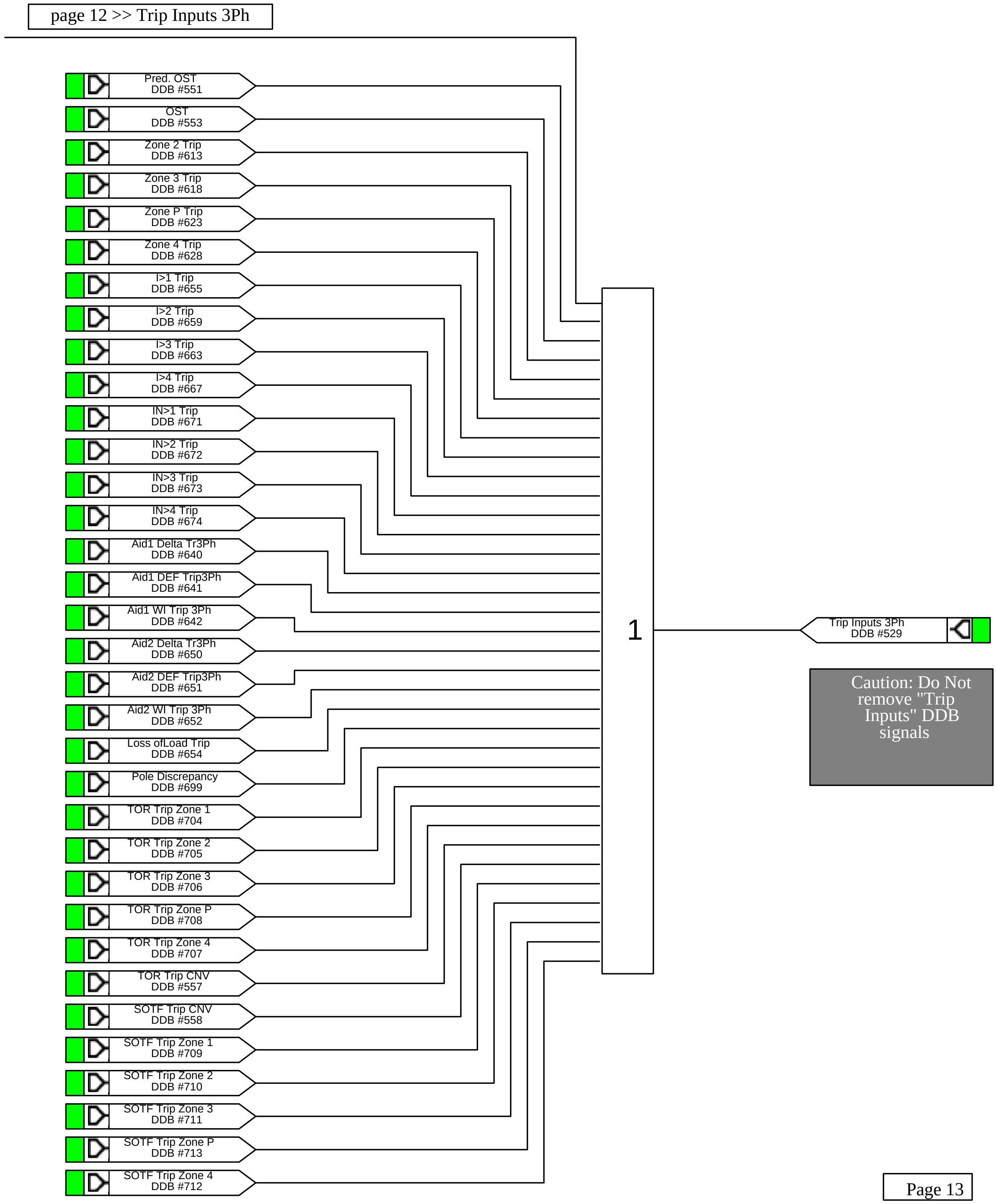


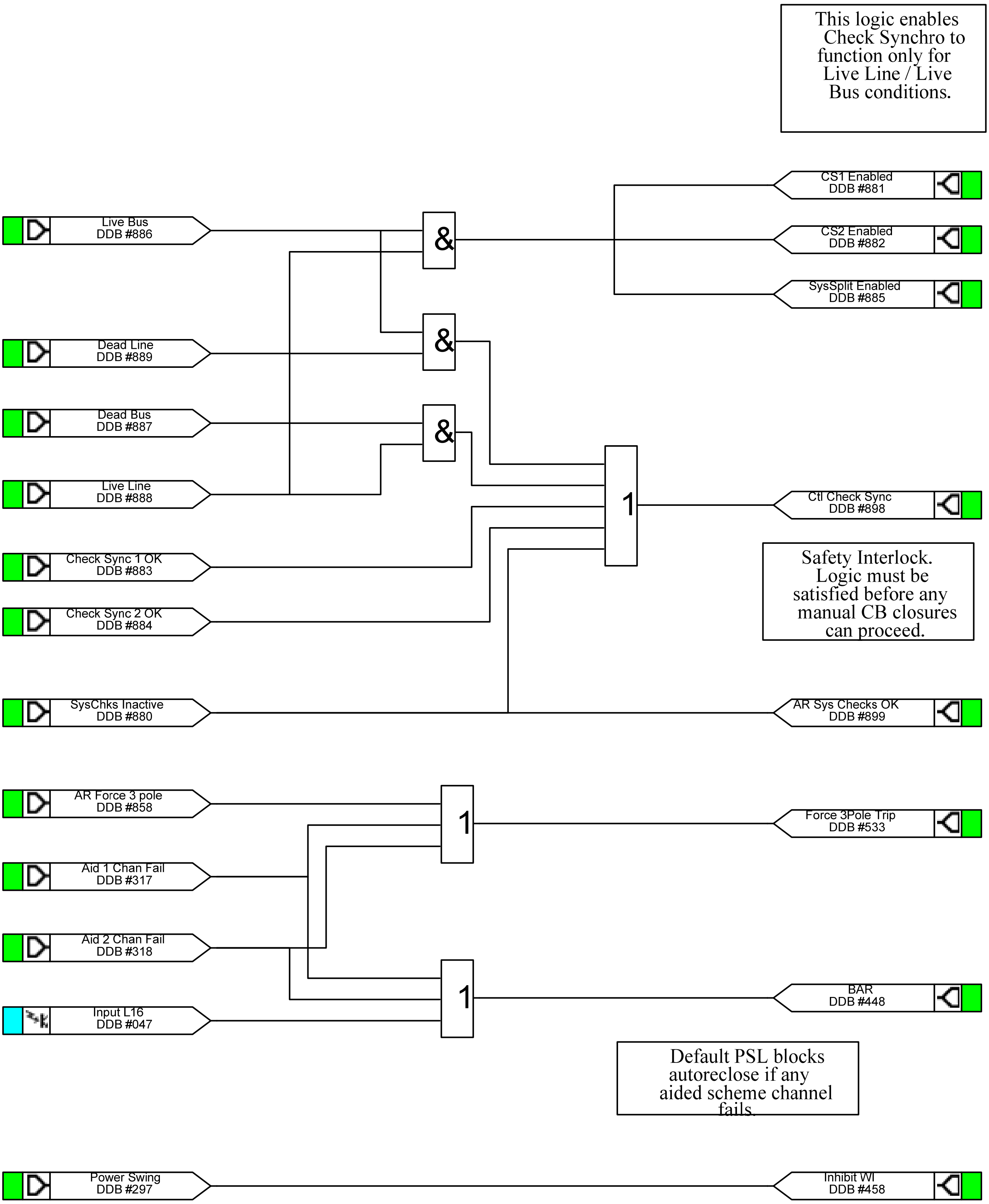
Inputs to Trip Conversion Logic:These Raw trip signals are then processed in relay fixed logic, to obtain the correct single, or three pole trip response.

Caution: Do Not remove "Trip Inputs" DDB signals

Zone 1 A Trip DDB #609
Aided 1 Trip A DDB #633
Aid 1 WI Trip A DDB #637
Aided 2 Trip A DDB #643
Aid 2 WI Trip A DDB #647
AR Trip Test A DDB #577
1
Trip Inputs A DDB #530
Zone 1 B Trip DDB #610
Aided 1 Trip B DDB #634
Aid 1 WI Trip B DDB #638
Aided 2 Trip B DDB #644
Aid 2 WI Trip B DDB #648
AR Trip Test B DDB #578
1
Trip Inputs B DDB #531
Zone 1 C Trip DDB #611
Aided 1 Trip C DDB #635
Aid 1 WI Trip C DDB #639
Aided 2 Trip C DDB #645
Aid 2 WI Trip C DDB #649
AR Trip Test C DDB #579
1
Trip Inputs C DDB #532
Page 11


AR Trip Test DDB #576
Broken Wire Trip DDB #679
Thermal Trip DDB #680
I2>1 Trip DDB #571
I2>2 Trip DDB #572
I2>3 Trip DDB #573
I2>4 Trip DDB #574
ISEF>1 Trip DDB #675
ISEF>2 Trip DDB #676
ISEF>3 Trip DDB #677
ISEF>4 Trip DDB #678
V<1 Trip DDB #683
V<2 Trip DDB #687
V>1 Trip DDB #691
V>2 Trip DDB #695
VN>1 Trip DDB #700
VN>2 Trip DDB #701
F<1 Trip DDB #1161
F<2 Trip DDB #1162
F<3 Trip DDB #1163
F<4 Trip DDB #1164
F>1 Trip DDB #1165
F>2 Trip DDB #1166
V1>1 Cmp Trip DDB #925
V1>2 Cmp Trip DDB #926
1
Trip Inputs 3Ph >> page 13
Caution: Do Not remove "Trip Inputs" DDB signals
Page 12


page 12 >> Trip Inputs 3Ph
Pred. OST DDB #551
OST DDB #553
Zone 2 Trip DDB #613
Zone 3 Trip DDB #618
Zone P Trip DDB #623
Zone 4 Trip DDB #628
I>1 Trip DDB #655
I>2 Trip DDB #659
I>3 Trip DDB #663
I>4 Trip DDB #667
IN>1 Trip DDB #671
IN>2 Trip DDB #672
IN>3 Trip DDB #673
IN>4 Trip DDB #674
Aid1 Delta Tr3Ph DDB #640
Aid1 DEF Trip3Ph DDB #641
Aid1 WI Trip 3Ph DDB #642
Aid2 Delta Tr3Ph DDB #650
Aid2 DEF Trip3Ph DDB #651
Aid2 WI Trip 3Ph DDB #652
Loss ofLoad Trip DDB #654
Pole Discrepancy DDB #699
TOR Trip Zone 1 DDB #704
TOR Trip Zone 2 DDB #705
TOR Trip Zone 3 DDB #706
TOR Trip Zone P DDB #708
TOR Trip Zone 4 DDB #707
TOR Trip CNV DDB #557
SOTF Trip CNV DDB #558
SOTF Trip Zone 1 DDB #709
SOTF Trip Zone 2 DDB #710
SOTF Trip Zone 3 DDB #711
SOTF Trip Zone P DDB #713
SOTF Trip Zone 4 DDB #712
1
Trip Inputs 3Ph DDB #529
Caution: Do Not remove "Trip Inputs" DDB signals
Page 13



This logic enables Check Synchro to function only for Live Line / Live Bus conditions.

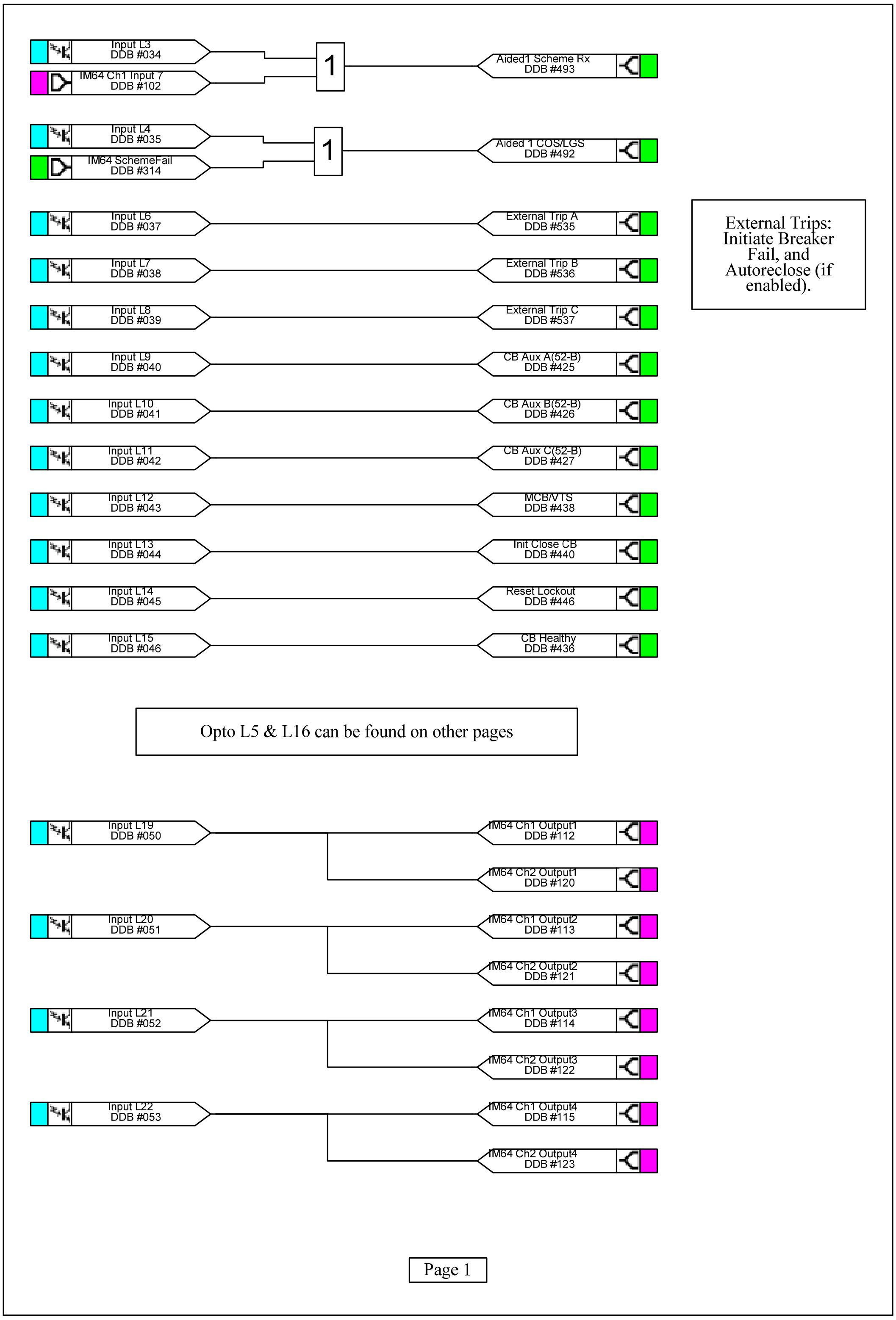
Safety Interlock. Logic must be satisfied before any manual CB closures can proceed.

Default PSL blocks autoreclose if any aided scheme channel fails.

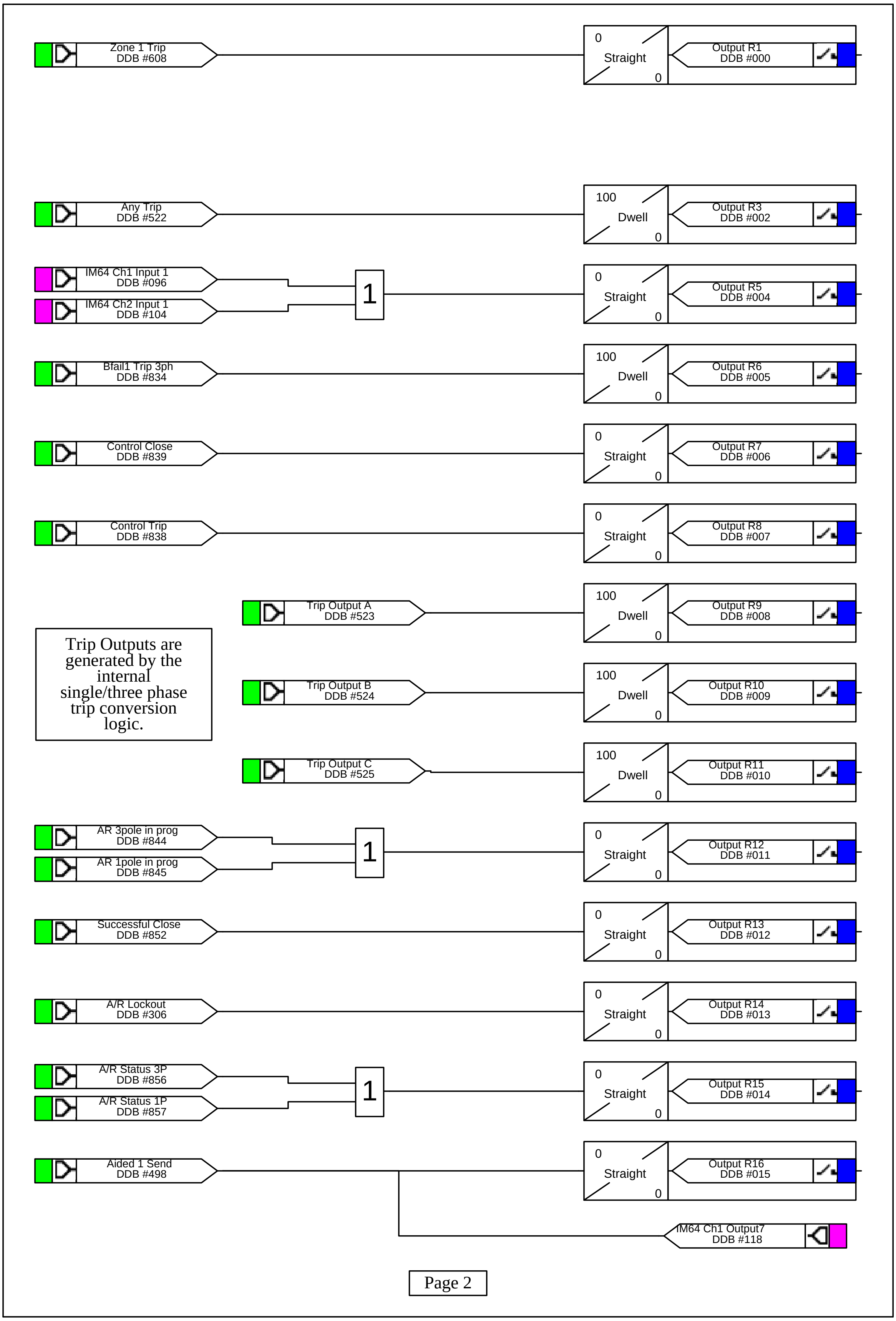
Live Bus DDB #886
Dead Line DDB #889
Dead Bus DDB #887
Live Line DDB #888
Check Sync 1 OK DDB #883
Check Sync 2 OK DDB #884
SysChks Inactive DDB #880
AR Force 3 pole DDB #858
Aid 1 Chan Fail DDB #317
Aid 2 Chan Fail DDB #318
Input L16 DDB #047
Power Swing DDB #297
&
&
&
1
1
1
CS1 Enabled DDB #881
CS2 Enabled DDB #882
SysSplit Enabled DDB #885
Ctl Check Sync DDB #898
AR Sys Checks OK DDB #899
Force 3Pole Trip DDB #533
BAR DDB #448
Inhibit WI DDB #458

P443 WITH STANDARD CONTACTS PSL 16 STD + 8 HIGH BREAK RELAYS

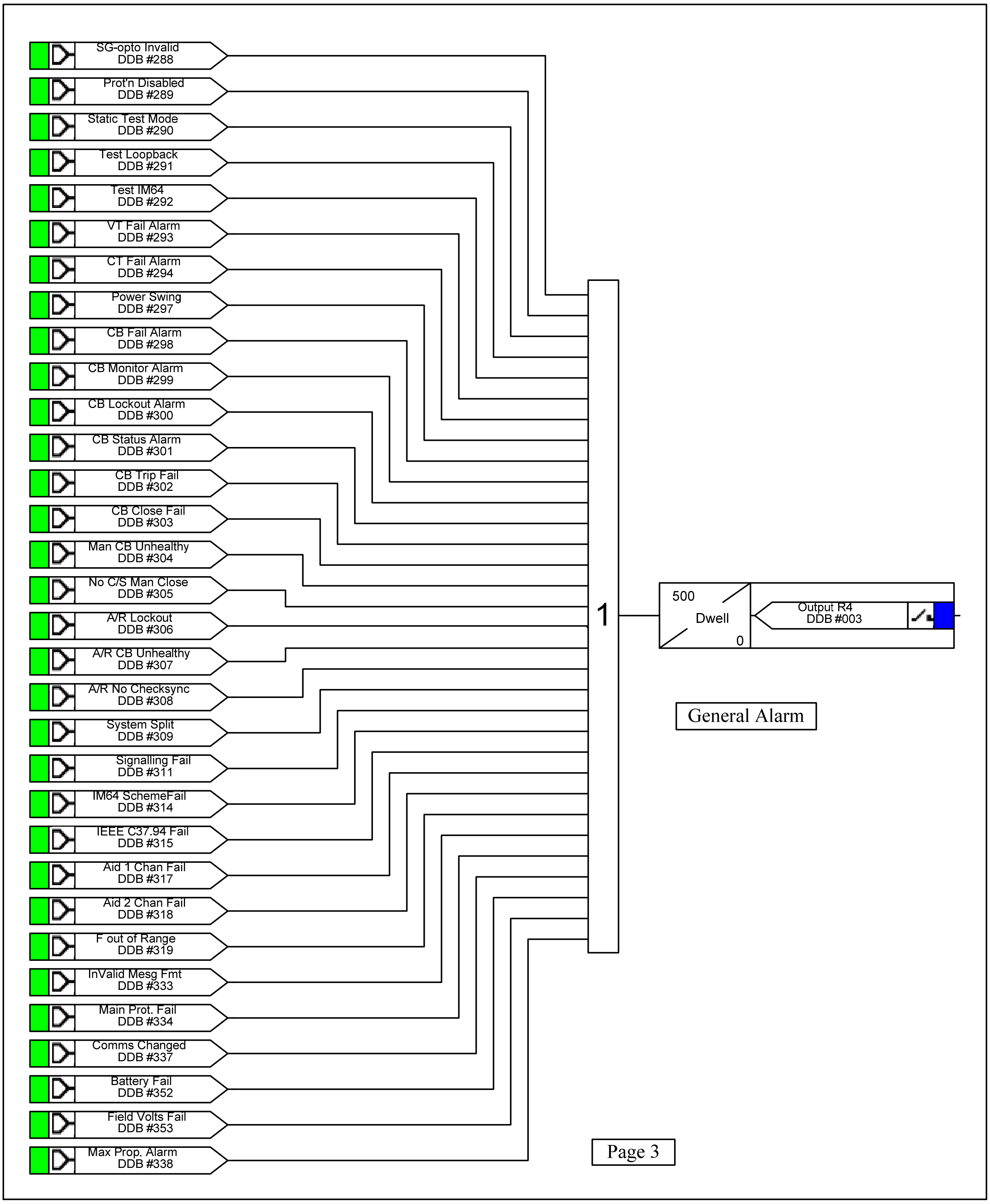
Opto Input Mappings

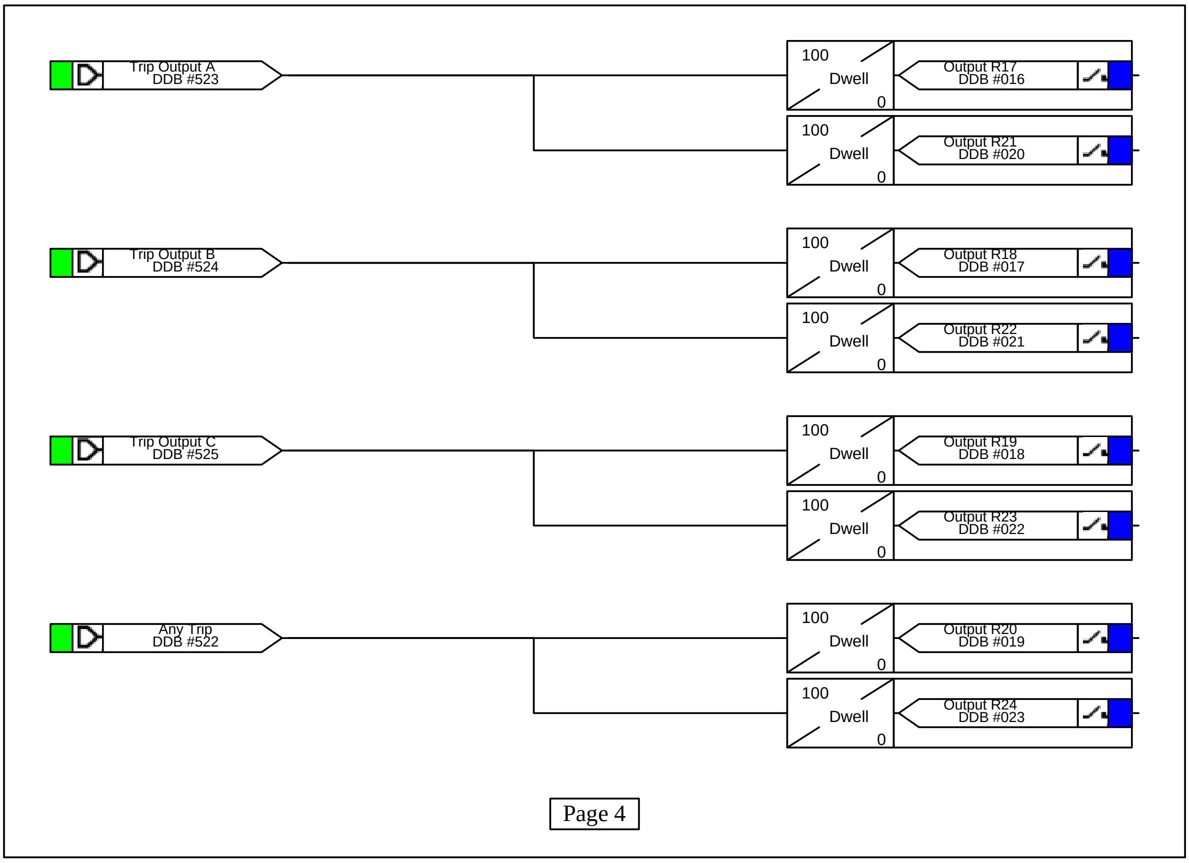

Input L3
DDB #034
IM64 Ch1 Input 7
DDB #102
1
Aided1 Scheme Rx
DDB #493
Input L4
DDB #035
IM64 SchemeFail
DDB #314
1
Aided 1 COS/LGS
DDB #492
Input L6
DDB #037
External Trip A
DDB #535
Input L7
DDB #038
External Trip B
DDB #536
Input L8
DDB #039
External Trip C
DDB #537
External Trips: Initiate Breaker Fail, and Autoreclose (if enabled).
Input L9
DDB #040
CB Aux A(52-B)
DDB #425
Input L10
DDB #041
CB Aux B(52-B)
DDB #426
Input L11
DDB #042
CB Aux C(52-B)
DDB #427
Input L12
DDB #043
MCB/VTS
DDB #438
Input L13
DDB #044
Init Close CB
DDB #440
Input L14
DDB #045
Reset Lockout
DDB #446
Input L15
DDB #046
CB Healthy
DDB #436
Opto L5 & L16 can be found on other pages
Input L19
DDB #050
IM64 Ch1 Output1
DDB #112
IM64 Ch2 Output1
DDB #120
Input L20
DDB #051
IM64 Ch1 Output2
DDB #113
IM64 Ch2 Output2
DDB #121
Input L21
DDB #052
IM64 Ch1 Output3
DDB #114
IM64 Ch2 Output3
DDB #122
Input L22
DDB #053
IM64 Ch1 Output4
DDB #115
IM64 Ch2 Output4
DDB #123
Page 1

Output Contacts

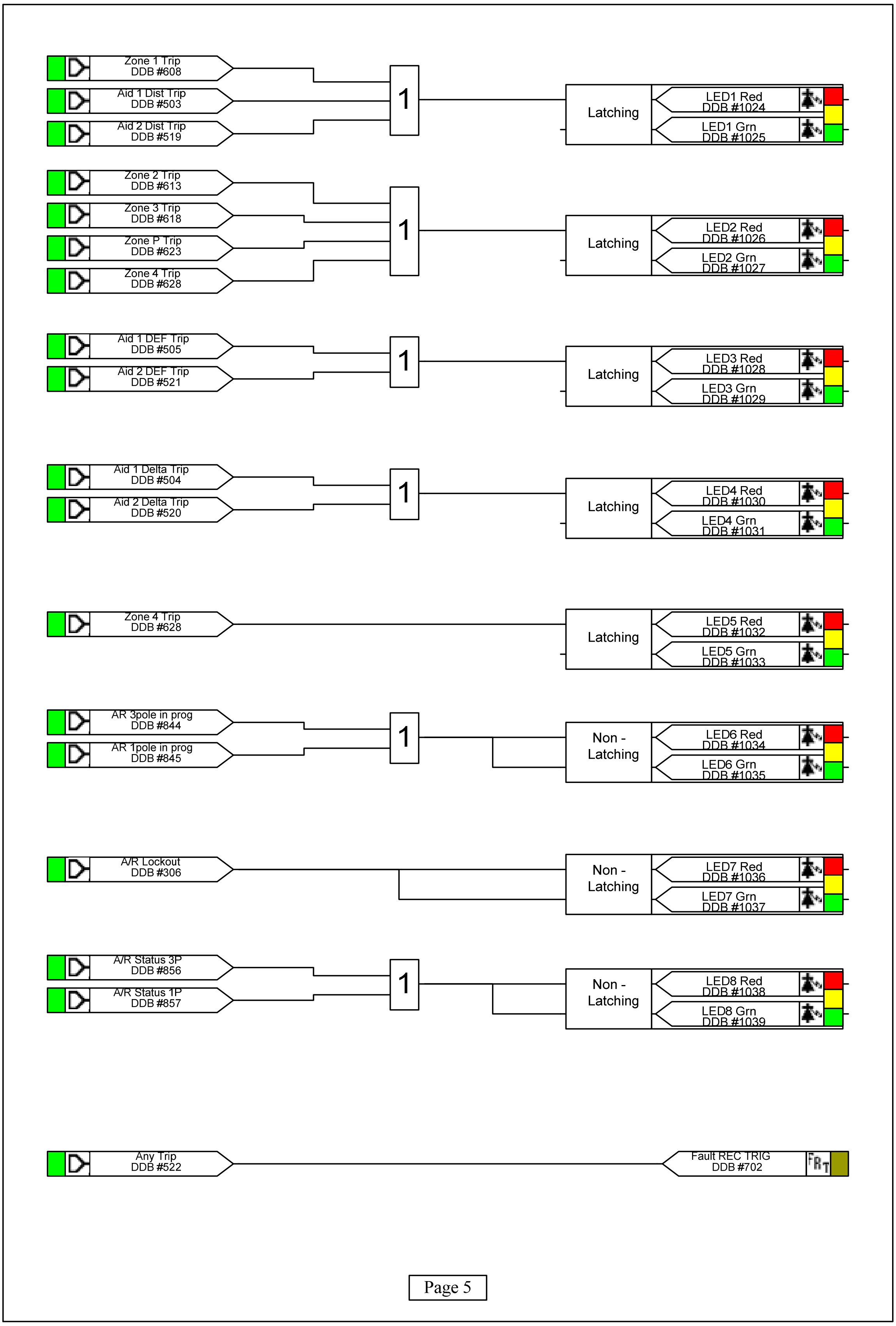

Zone 1 Trip DDB #608
0 Straight 0
Output R1 DDB #000
Any Trip DDB #522
100 Dwell 0
Output R3 DDB #002
IM64 Ch1 Input 1 DDB #096
IM64 Ch2 Input 1 DDB #104
1
0 Straight 0
Output R5 DDB #004
Bfail1 Trip 3ph DDB #834
100 Dwell 0
Output R6 DDB #005
Control Close DDB #839
0 Straight 0
Output R7 DDB #006
Control Trip DDB #838
0 Straight 0
Output R8 DDB #007
Trip Output A DDB #523
100 Dwell 0
Output R9 DDB #008
Trip Output B DDB #524
100 Dwell 0
Output R10 DDB #009
Trip Output C DDB #525
100 Dwell 0
Output R11 DDB #010
AR 3pole in prog DDB #844
AR 1pole in prog DDB #845
1
0 Straight 0
Output R12 DDB #011
Successful Close DDB #852
0 Straight 0
Output R13 DDB #012
A/R Lockout DDB #306
0 Straight 0
Output R14 DDB #013
A/R Status 3P DDB #856
A/R Status 1P DDB #857
1
0 Straight 0
Output R15 DDB #014
Aided 1 Send DDB #498
0 Straight 0
Output R16 DDB #015
IM64 Ch1 Output7 DDB #118
Page 2

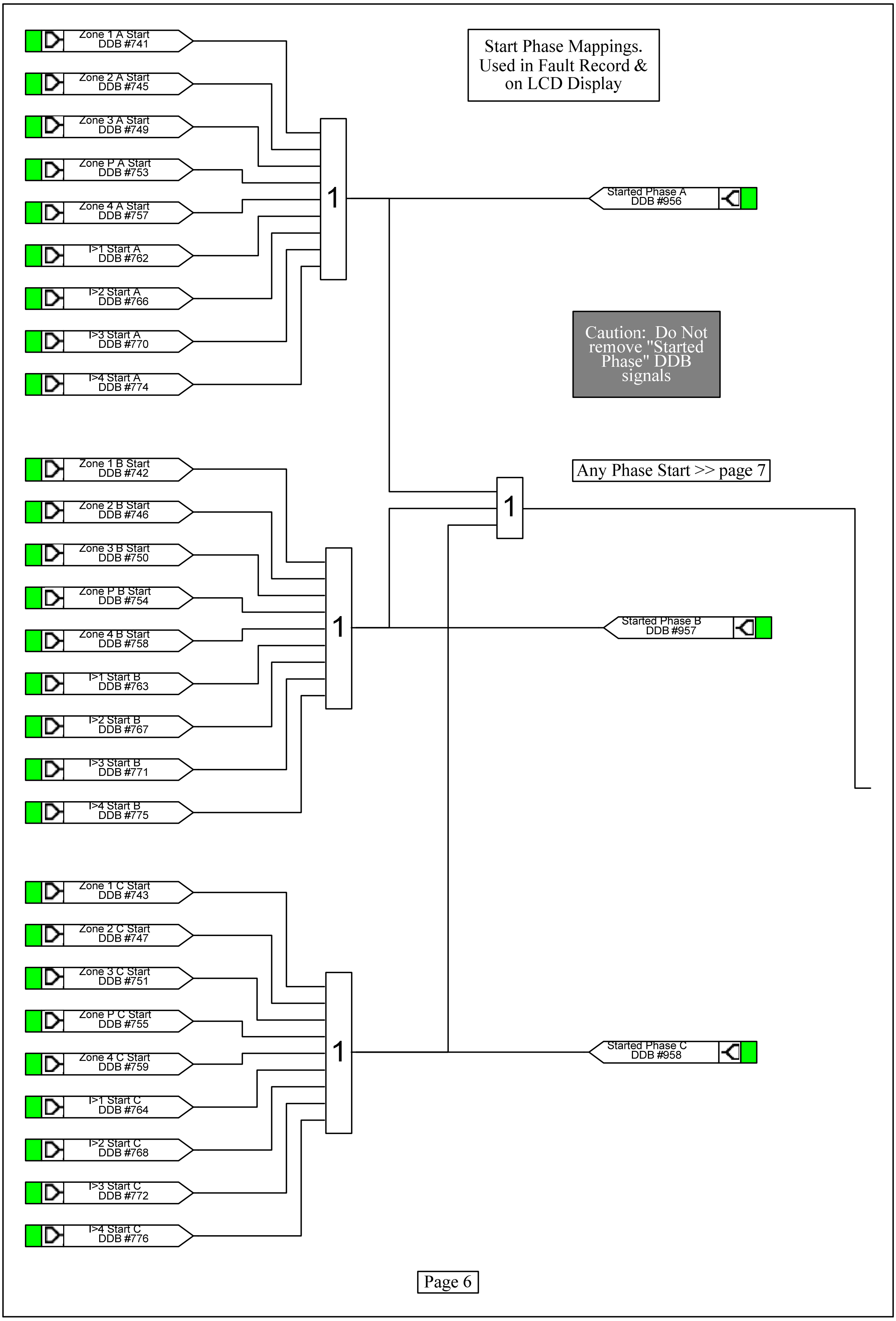
Trip Outputs are generated by the internal single/three phase trip conversion logic.

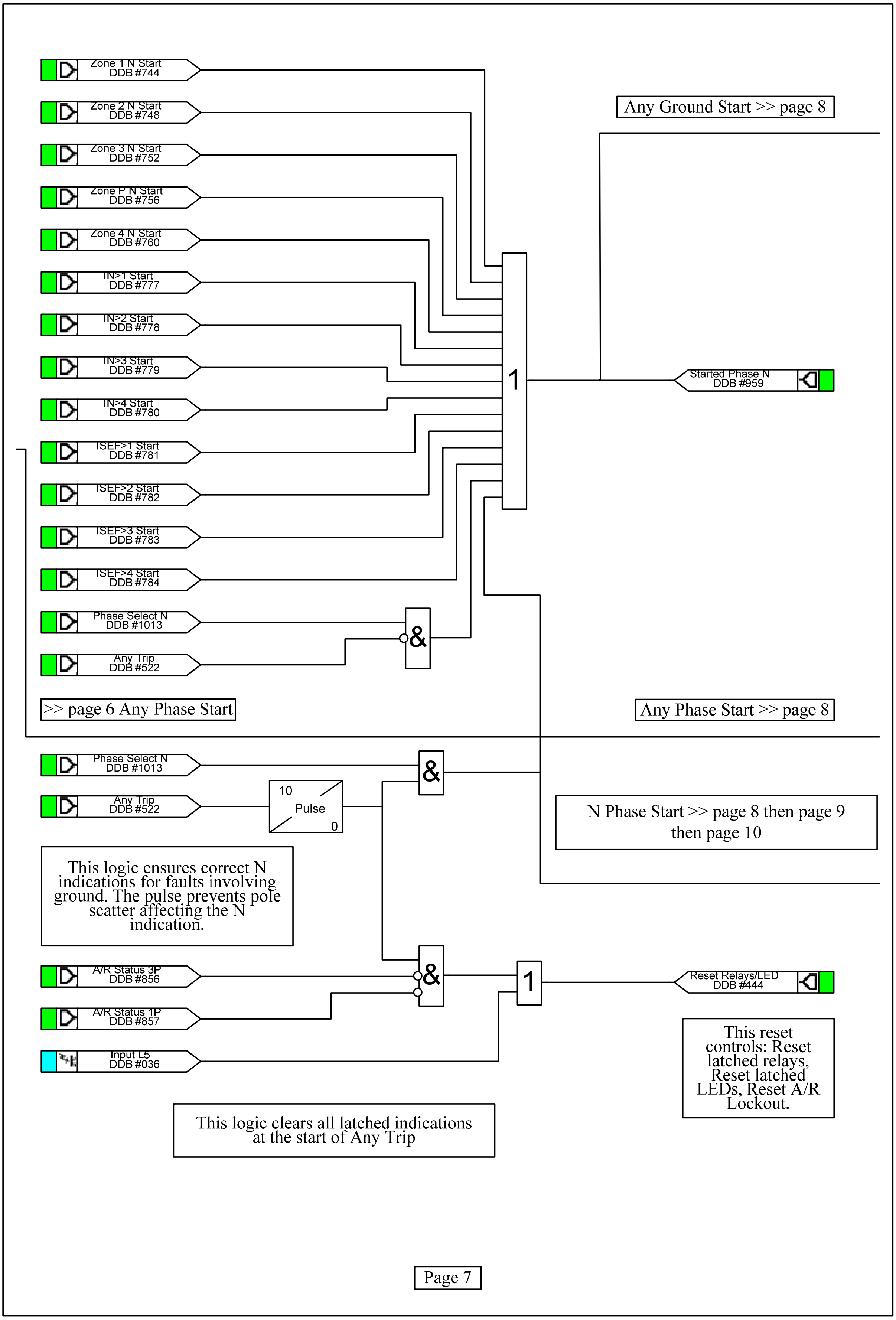

SG-opto Invalid DDB #288
Prot'n Disabled DDB #289
Static Test Mode DDB #290
Test Loopback DDB #291
Test IM64 DDB #292
VT Fail Alarm DDB #293
CT Fail Alarm DDB #294
Power Swing DDB #297
CB Fail Alarm DDB #298
CB Monitor Alarm DDB #299
CB Lockout Alarm DDB #300
CB Status Alarm DDB #301
CB Trip Fail DDB #302
CB Close Fail DDB #303
Man CB Unhealthy DDB #304
No C/S Man Close DDB #305
A/R Lockout DDB #306
A/R CB Unhealthy DDB #307
A/R No Checksync DDB #308
System Split DDB #309
Signalling Fail DDB #311
IM64 SchemeFail DDB #314
IEEE C37.94 Fail DDB #315
Aid 1 Chan Fail DDB #317
Aid 2 Chan Fail DDB #318
F out of Range DDB #319
InValid Mesg Fmt DDB #333
Main Prot. Fail DDB #334
Comms Changed DDB #337
Battery Fail DDB #352
Field Volts Fail DDB #353
Max Prop. Alarm DDB #338
1
500
Dwell
0
Output R4 DDB #003
General Alarm
Page 3


Trip Output A
DDB #523
Trip Output B
DDB #524
Trip Output C
DDB #525
Any Trip
DDB #522
100
Dwell
0
Output R17
DDB #016
Output R21
DDB #020
Output R18
DDB #017
Output R22
DDB #021
Output R19
DDB #018
Output R23
DDB #022
Output R20
DDB #019
Output R24
DDB #023
Page 4

LEDs


Zone 1 Trip DDB #608
Aid 1 Dist Trip DDB #503
Aid 2 Dist Trip DDB #519
1
Latching
LED1 Red DDB #1024
LED1 Grn DDB #1025
Zone 2 Trip DDB #613
Zone 3 Trip DDB #618
Zone P Trip DDB #623
Zone 4 Trip DDB #628
1
Latching
LED2 Red DDB #1026
LED2 Grn DDB #1027
Aid 1 DEF Trip DDB #505
Aid 2 DEF Trip DDB #521
1
Latching
LED3 Red DDB #1028
LED3 Grn DDB #1029
Aid 1 Delta Trip DDB #504
Aid 2 Delta Trip DDB #520
1
Latching
LED4 Red DDB #1030
LED4 Grn DDB #1031
Zone 4 Trip DDB #628
Latching
LED5 Red DDB #1032
LED5 Grn DDB #1033
AR 3pole in prog DDB #844
AR 1pole in prog DDB #845
1
Non - Latching
LED6 Red DDB #1034
LED6 Grn DDB #1035
A/R Lockout DDB #306
Non - Latching
LED7 Red DDB #1036
LED7 Grn DDB #1037
A/R Status 3P DDB #856
A/R Status 1P DDB #857
1
Non - Latching
LED8 Red DDB #1038
LED8 Grn DDB #1039
Any Trip DDB #522
Fault REC TRIG DDB #702
FRT
Page 5

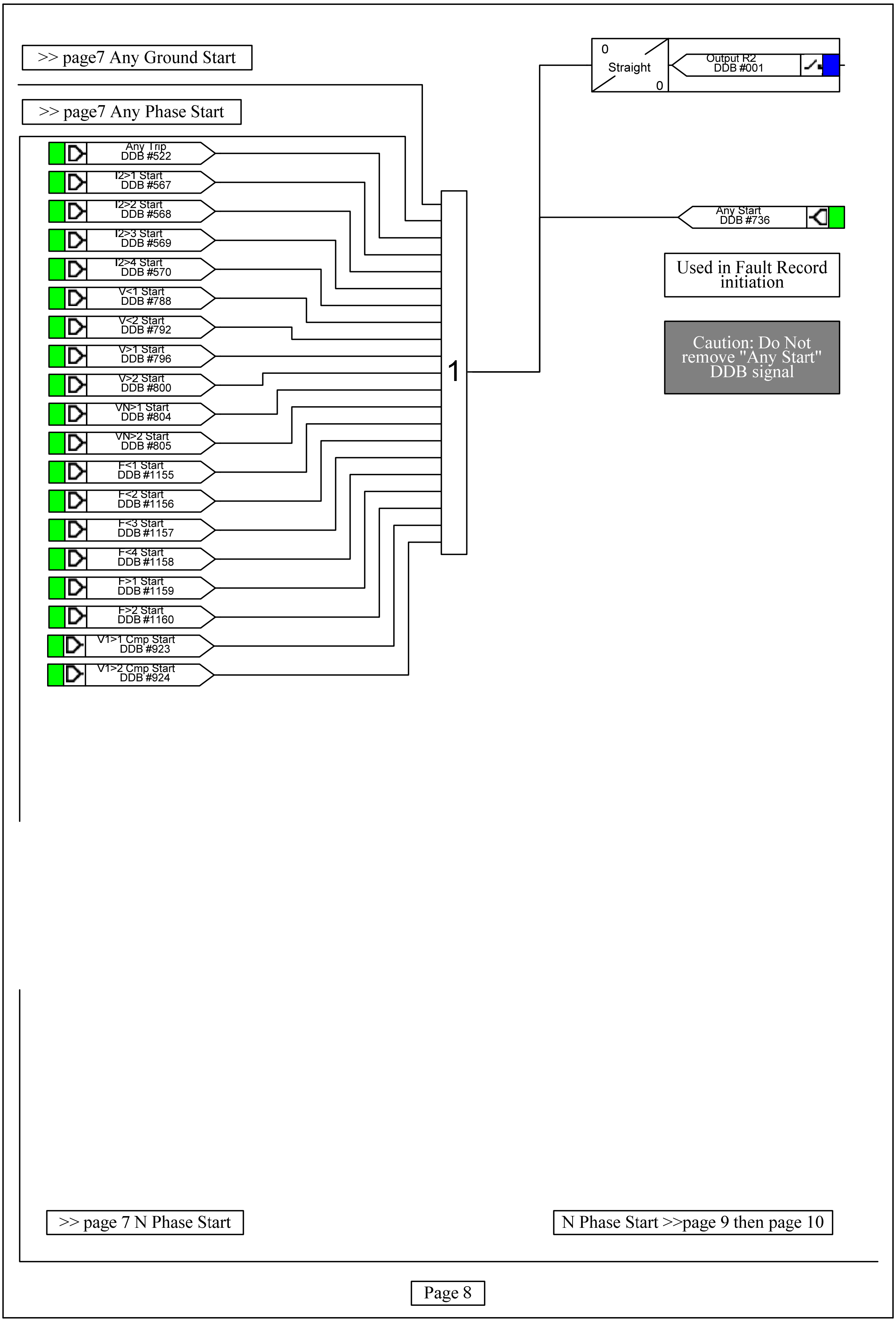

Zone 1 A Start DDB #741
Zone 2 A Start DDB #745
Zone 3 A Start DDB #749
Zone P A Start DDB #753
Zone 4 A Start DDB #757
I>1 Start A DDB #762
I>2 Start A DDB #766
I>3 Start A DDB #770
I>4 Start A DDB #774
Start Phase Mappings. Used in Fault Record & on LCD Display
1
Started Phase A DDB #956
Caution: Do Not remove "Started Phase" DDB signals
Any Phase Start >> page 7
Zone 1 B Start DDB #742
Zone 2 B Start DDB #746
Zone 3 B Start DDB #750
Zone P B Start DDB #754
Zone 4 B Start DDB #758
I>1 Start B DDB #763
I>2 Start B DDB #767
I>3 Start B DDB #771
I>4 Start B DDB #775
1
1
Started Phase B DDB #957
Zone 1 C Start DDB #743
Zone 2 C Start DDB #747
Zone 3 C Start DDB #751
Zone P C Start DDB #755
Zone 4 C Start DDB #759
I>1 Start C DDB #764
I>2 Start C DDB #768
I>3 Start C DDB #772
I>4 Start C DDB #776
1
Started Phase C DDB #958
Page 6

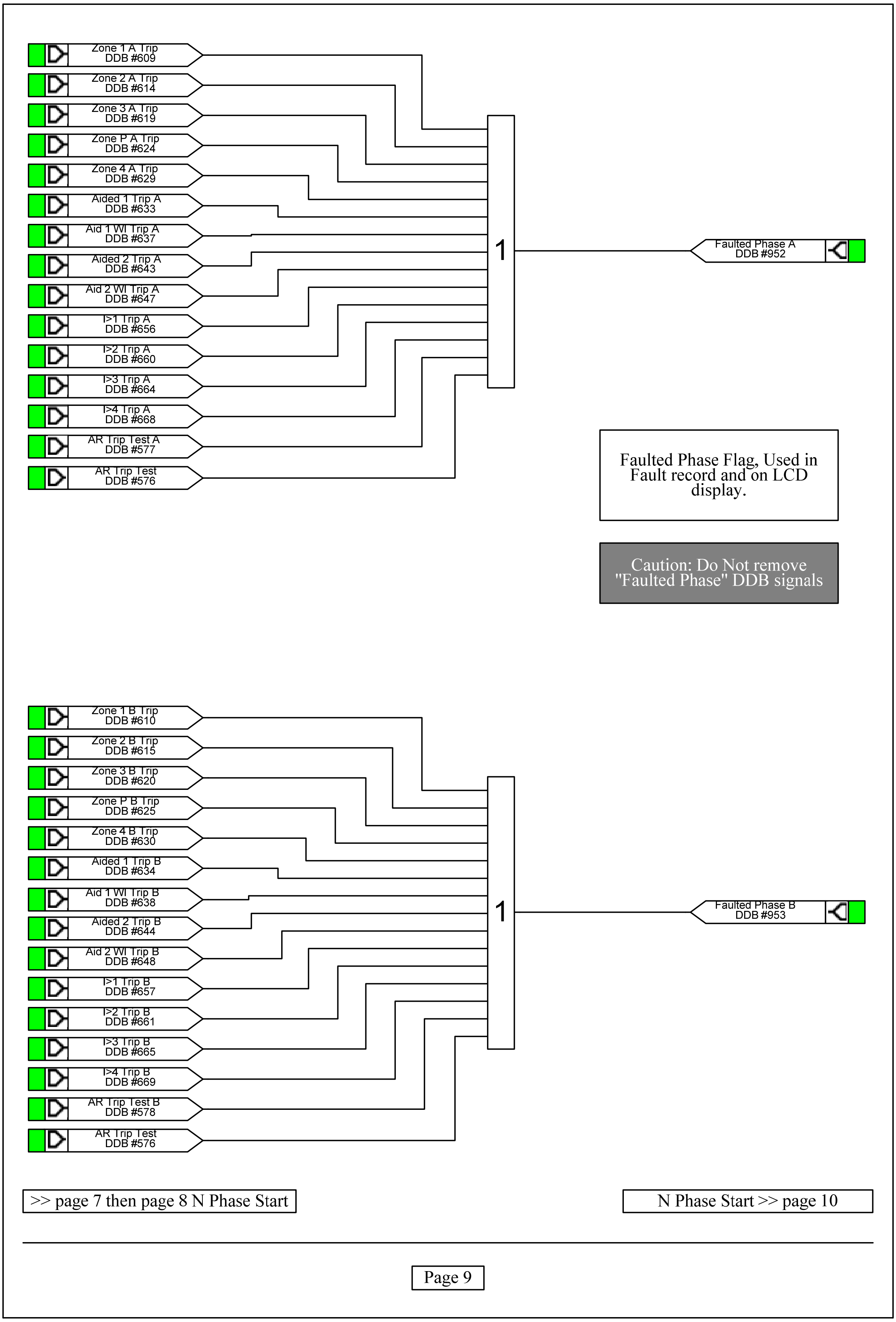

Zone 1 N Start DDB #744
Zone 2 N Start DDB #748
Zone 3 N Start DDB #752
Zone P N Start DDB #756
Zone 4 N Start DDB #760
IN>1 Start DDB #777
IN>2 Start DDB #778
IN>3 Start DDB #779
IN>4 Start DDB #780
ISEF>1 Start DDB #781
ISEF>2 Start DDB #782
ISEF>3 Start DDB #783
ISEF>4 Start DDB #784
Phase Select N DDB #1013
Any Trip DDB #522
&
1
Any Ground Start >> page 8
Started Phase N DDB #959
>> page 6 Any Phase Start
Any Phase Start >> page 8
Phase Select N DDB #1013
Any Trip DDB #522
10
Pulse
0
&
N Phase Start >> page 8 then page 9 then page 10
A/R Status 3P DDB #856
A/R Status 1P DDB #857
Input L5 DDB #036
&
1
Reset Relays/LED DDB #444
Page 7

This logic ensures correct N indications for faults involving ground. The pulse prevents pole scatter affecting the N indication.

This reset controls: Reset latched relays, Reset latched LEDs, Reset A/R Lockout.

This logic clears all latched indications at the start of Any Trip


>> page7 Any Ground Start
>> page7 Any Phase Start
Any Trip DDB #522
I2>1 Start DDB #567
I2>2 Start DDB #568
I2>3 Start DDB #569
I2>4 Start DDB #570
V<1 Start DDB #788
V<2 Start DDB #792
V>1 Start DDB #796
V>2 Start DDB #800
VN>1 Start DDB #804
VN>2 Start DDB #805
F<1 Start DDB #1155
F<2 Start DDB #1156
F<3 Start DDB #1157
F<4 Start DDB #1158
F>1 Start DDB #1159
F>2 Start DDB #1160
V1>1 Cmp Start DDB #923
V1>2 Cmp Start DDB #924
1
0
Straight
0
Output R2 DDB #001
Any Start DDB #736
Used in Fault Record initiation
Caution: Do Not remove "Any Start" DDB signal
>> page 7 N Phase Start
N Phase Start >>page 9 then page 10
Page 8


Zone 1 A Trip DDB #609
Zone 2 A Trip DDB #614
Zone 3 A Trip DDB #619
Zone P A Trip DDB #624
Zone 4 A Trip DDB #629
Aided 1 Trip A DDB #633
Aid 1 WI Trip A DDB #637
Aided 2 Trip A DDB #643
Aid 2 WI Trip A DDB #647
I>1 Trip A DDB #656
I>2 Trip A DDB #660
I>3 Trip A DDB #664
I>4 Trip A DDB #668
AR Trip Test A DDB #577
AR Trip Test DDB #576
1
Faulted Phase A DDB #952
Zone 1 B Trip DDB #610
Zone 2 B Trip DDB #615
Zone 3 B Trip DDB #620
Zone P B Trip DDB #625
Zone 4 B Trip DDB #630
Aided 1 Trip B DDB #634
Aid 1 WI Trip B DDB #638
Aided 2 Trip B DDB #644
Aid 2 WI Trip B DDB #648
I>1 Trip B DDB #657
I>2 Trip B DDB #661
I>3 Trip B DDB #665
I>4 Trip B DDB #669
AR Trip Test B DDB #578
AR Trip Test DDB #576
1
Faulted Phase B DDB #953

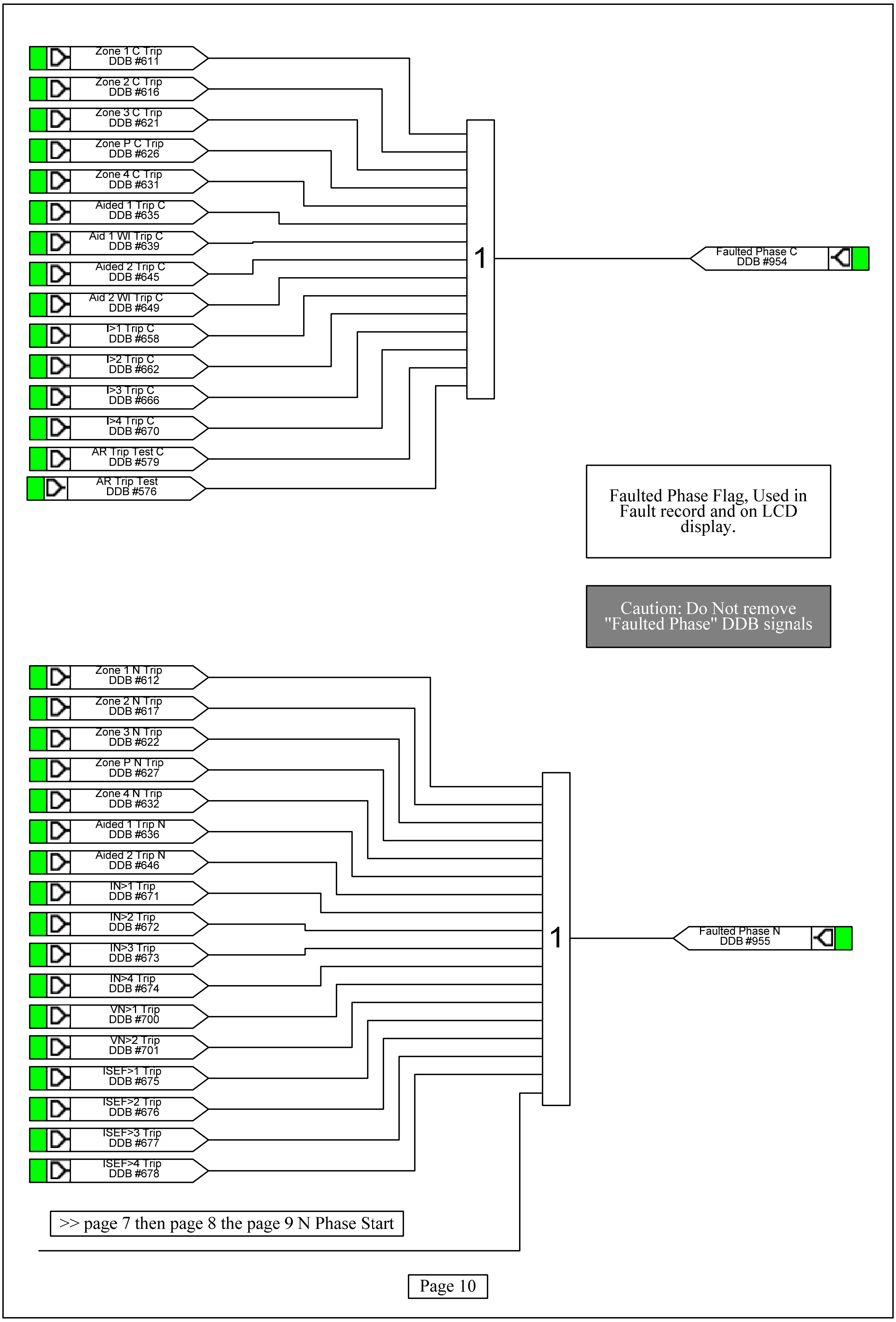
Faulted Phase Flag, Used in Fault record and on LCD display.

Caution: Do Not remove "Faulted Phase" DDB signals

>> page 7 then page 8 N Phase Start

N Phase Start >> page 10

Page 9

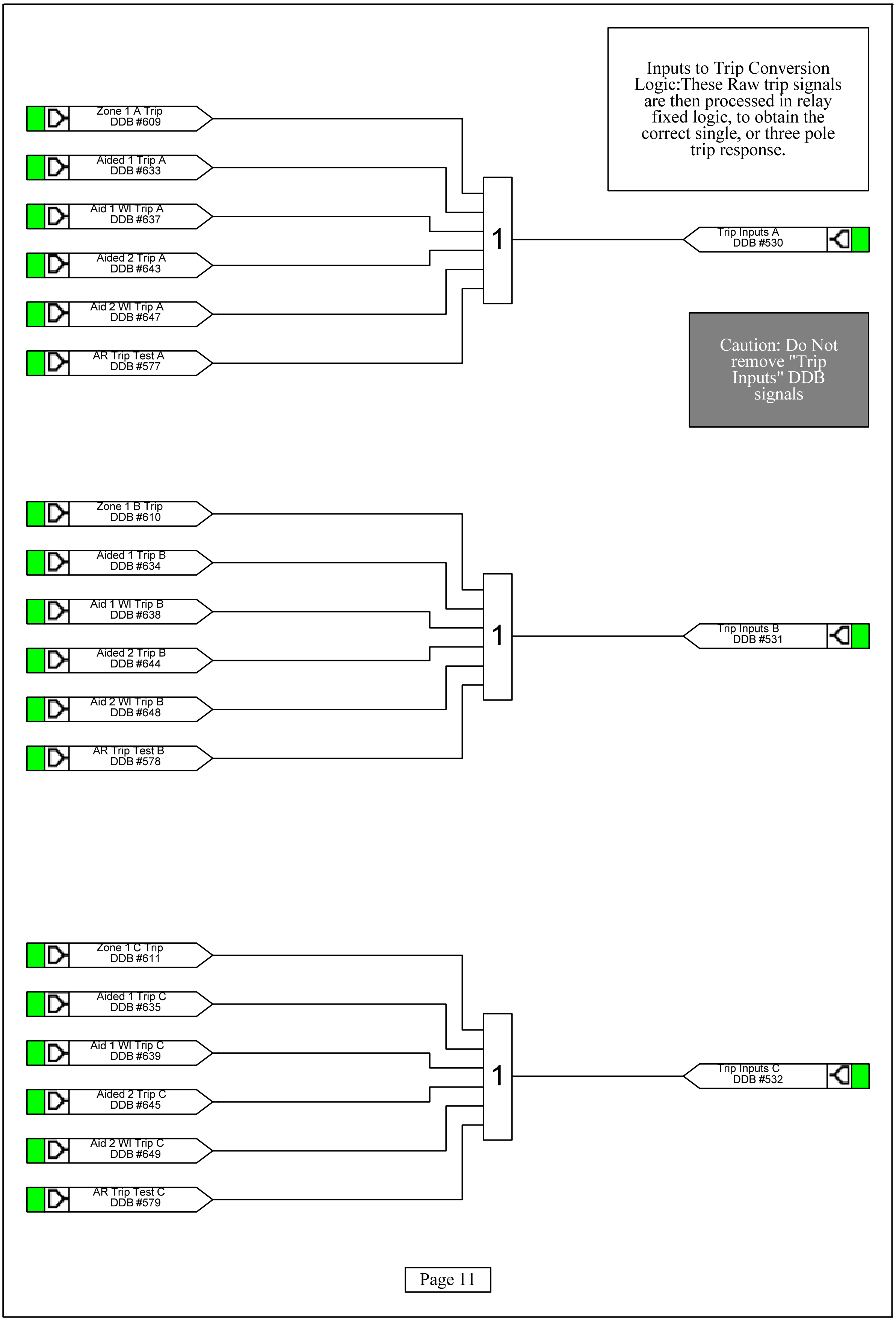

Zone 1 C Trip DDB #611
Zone 2 C Trip DDB #616
Zone 3 C Trip DDB #621
Zone P C Trip DDB #626
Zone 4 C Trip DDB #631
Aided 1 Trip C DDB #635
Aid 1 WI Trip C DDB #639
Aided 2 Trip C DDB #645
Aid 2 WI Trip C DDB #649
I>1 Trip C DDB #658
I>2 Trip C DDB #662
I>3 Trip C DDB #666
I>4 Trip C DDB #670
AR Trip Test C DDB #579
AR Trip Test DDB #576
1
Faulted Phase C DDB #954
Zone 1 N Trip DDB #612
Zone 2 N Trip DDB #617
Zone 3 N Trip DDB #622
Zone P N Trip DDB #627
Zone 4 N Trip DDB #632
Aided 1 Trip N DDB #636
Aided 2 Trip N DDB #646
IN>1 Trip DDB #671
IN>2 Trip DDB #672
IN>3 Trip DDB #673
IN>4 Trip DDB #674
VN>1 Trip DDB #700
VN>2 Trip DDB #701
ISEF>1 Trip DDB #675
ISEF>2 Trip DDB #676
ISEF>3 Trip DDB #677
ISEF>4 Trip DDB #678
1
Faulted Phase N DDB #955

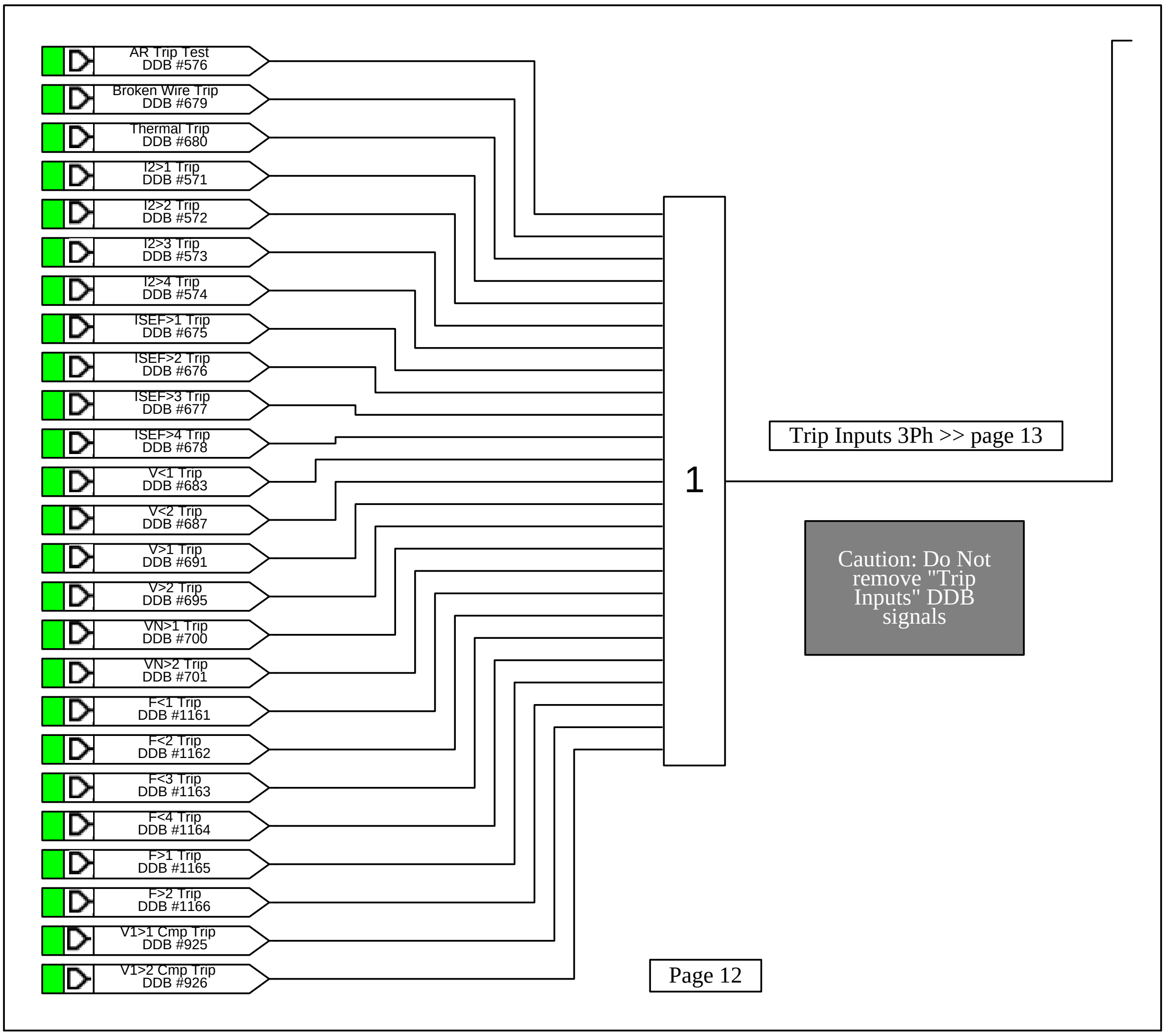
Faulted Phase Flag, Used in Fault record and on LCD display.

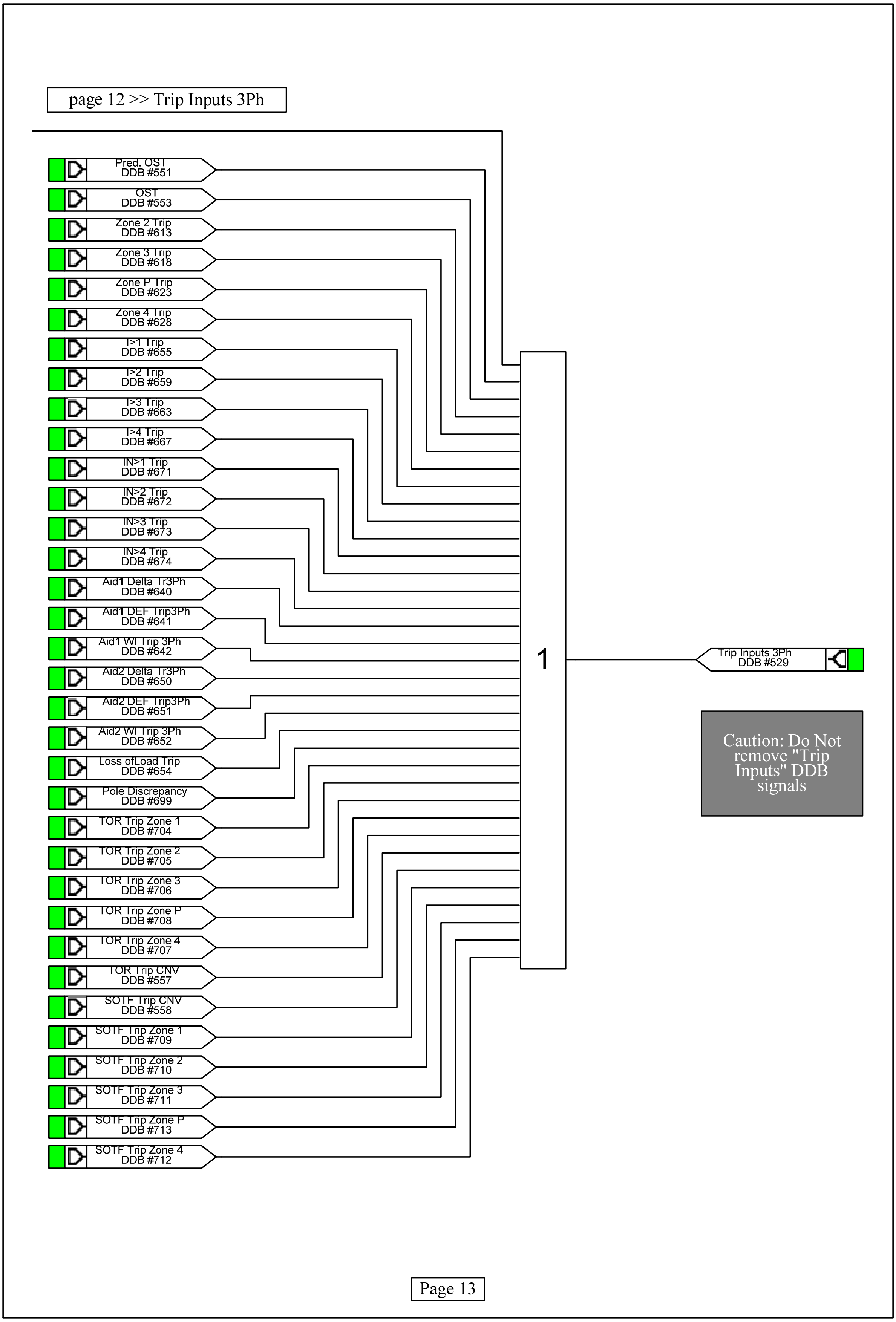
Caution: Do Not remove "Faulted Phase" DDB signals

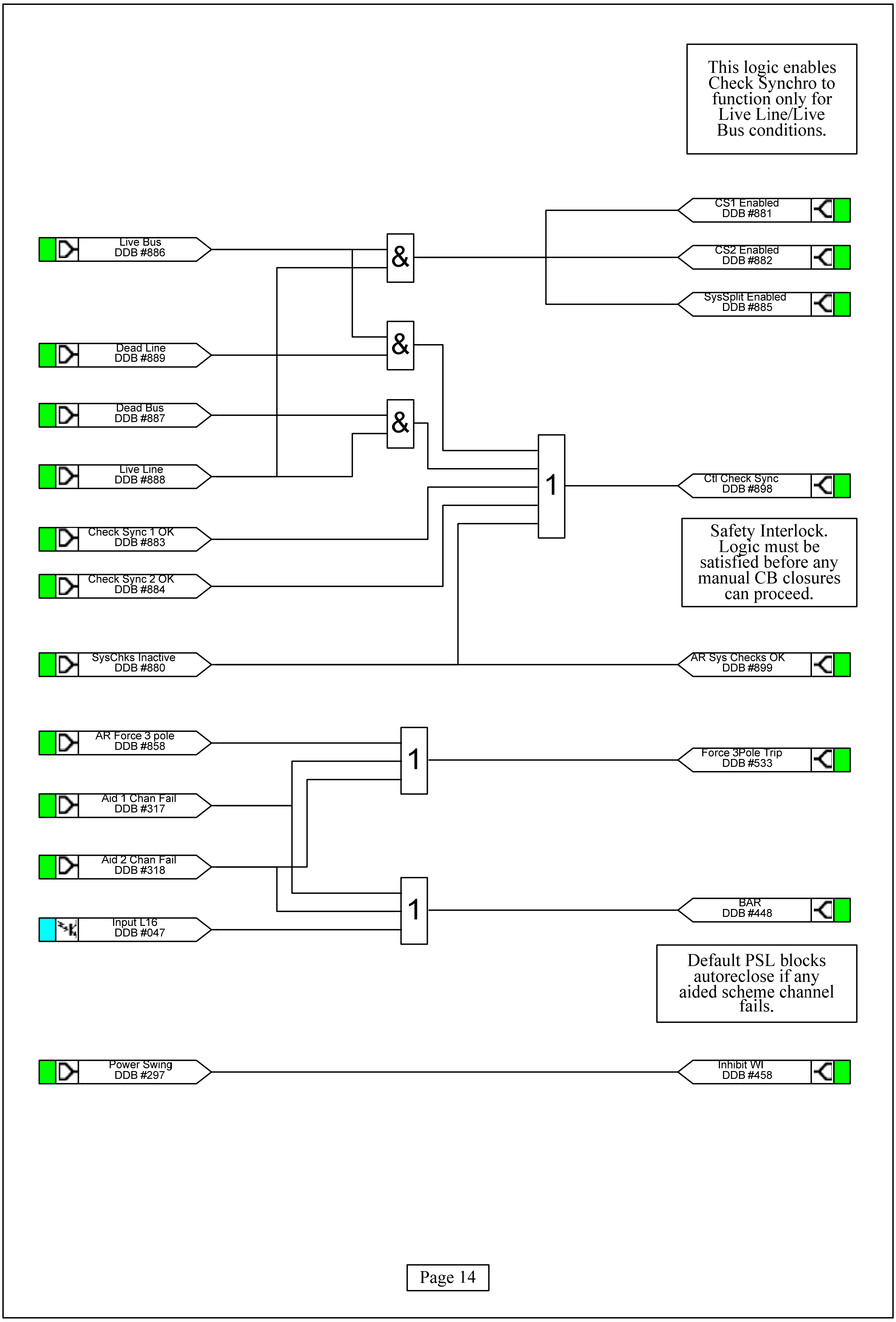
>> page 7 then page 8 the page 9 N Phase Start

Page 10


Inputs to Trip Conversion Logic:These Raw trip signals are then processed in relay fixed logic, to obtain the correct single, or three pole trip response.
Zone 1 A Trip DDB #609
Aided 1 Trip A DDB #633
Aid 1 WI Trip A DDB #637
Aided 2 Trip A DDB #643
Aid 2 WI Trip A DDB #647
AR Trip Test A DDB #577
1
Trip Inputs A DDB #530
Caution: Do Not remove "Trip Inputs" DDB signals
Zone 1 B Trip DDB #610
Aided 1 Trip B DDB #634
Aid 1 WI Trip B DDB #638
Aided 2 Trip B DDB #644
Aid 2 WI Trip B DDB #648
AR Trip Test B DDB #578
1
Trip Inputs B DDB #531
Zone 1 C Trip DDB #611
Aided 1 Trip C DDB #635
Aid 1 WI Trip C DDB #639
Aided 2 Trip C DDB #645
Aid 2 WI Trip C DDB #649
AR Trip Test C DDB #579
1
Trip Inputs C DDB #532
Page 11

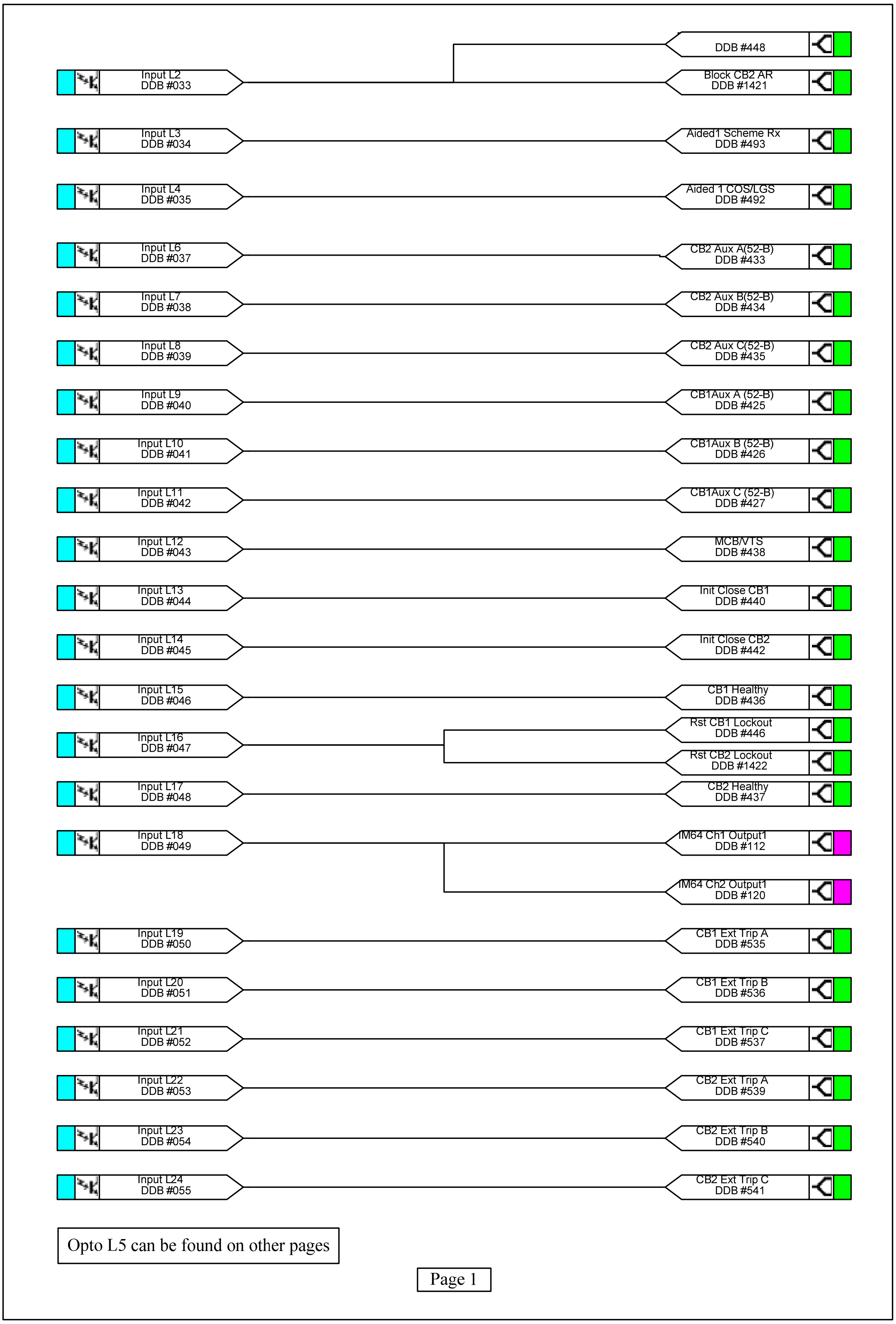

AR Trip Test
DDB #576
Broken Wire Trip
DDB #679
Thermal Trip
DDB #680
I2>1 Trip
DDB #571
I2>2 Trip
DDB #572
I2>3 Trip
DDB #573
I2>4 Trip
DDB #574
ISEF>1 Trip
DDB #675
ISEF>2 Trip
DDB #676
ISEF>3 Trip
DDB #677
ISEF>4 Trip
DDB #678
V<1 Trip
DDB #683
V<2 Trip
DDB #687
V>1 Trip
DDB #691
V>2 Trip
DDB #695
VN>1 Trip
DDB #700
VN>2 Trip
DDB #701
F<1 Trip
DDB #1161
F<2 Trip
DDB #1162
F<3 Trip
DDB #1163
F<4 Trip
DDB #1164
F>1 Trip
DDB #1165
F>2 Trip
DDB #1166
V1>1 Cmp Trip
DDB #925
V1>2 Cmp Trip
DDB #926
1
Trip Inputs 3Ph >> page 13
Caution: Do Not remove "Trip Inputs" DDB signals
Page 12


page 12 >> Trip Inputs 3Ph
Pred. OST DDB #551
OST DDB #553
Zone 2 Trip DDB #613
Zone 3 Trip DDB #618
Zone P Trip DDB #623
Zone 4 Trip DDB #628
I>1 Trip DDB #655
I>2 Trip DDB #659
I>3 Trip DDB #663
I>4 Trip DDB #667
IN>1 Trip DDB #671
IN>2 Trip DDB #672
IN>3 Trip DDB #673
IN>4 Trip DDB #674
Aid1 Delta Tr3Ph DDB #640
Aid1 DEF Trip3Ph DDB #641
Aid1 WI Trip 3Ph DDB #642
Aid2 Delta Tr3Ph DDB #650
Aid2 DEF Trip3Ph DDB #651
Aid2 WI Trip 3Ph DDB #652
Loss ofLoad Trip DDB #654
Pole Discrepancy DDB #699
TOR Trip Zone 1 DDB #704
TOR Trip Zone 2 DDB #705
TOR Trip Zone 3 DDB #706
TOR Trip Zone P DDB #708
TOR Trip Zone 4 DDB #707
TOR Trip CNV DDB #557
SOTF Trip CNV DDB #558
SOTF Trip Zone 1 DDB #709
SOTF Trip Zone 2 DDB #710
SOTF Trip Zone 3 DDB #711
SOTF Trip Zone P DDB #713
SOTF Trip Zone 4 DDB #712
1
Trip Inputs 3Ph DDB #529
Caution: Do Not remove "Trip Inputs" DDB signals
Page 13

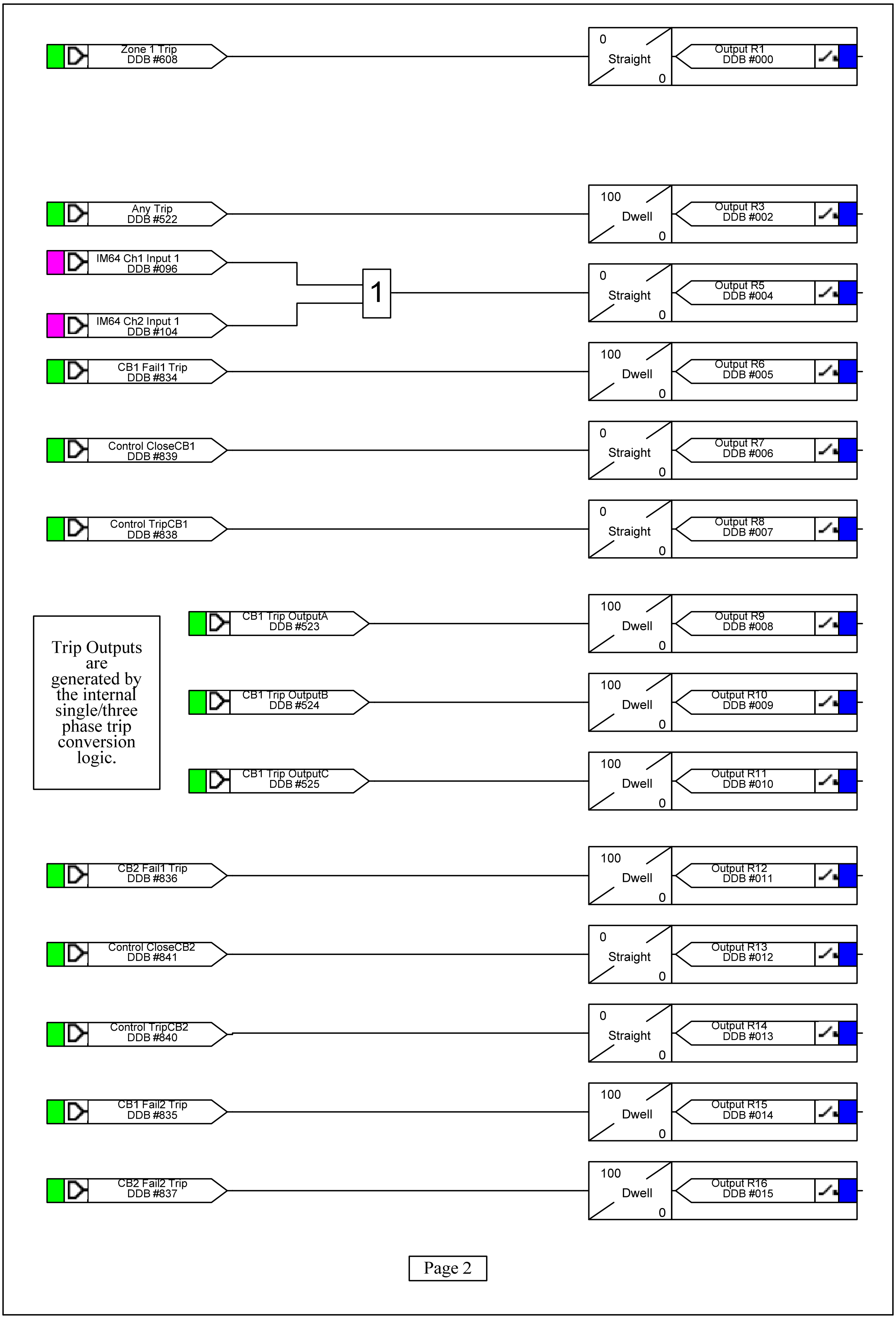

This logic enables Check Synchro to function only for Live Line/Live Bus conditions.
CS1 Enabled DDB #881
CS2 Enabled DDB #882
SysSplit Enabled DDB #885
Live Bus DDB #886
&
&
&
Dead Line DDB #889
Dead Bus DDB #887
Live Line DDB #888
1
Ctl Check Sync DDB #898
Check Sync 1 OK DDB #883
Check Sync 2 OK DDB #884
Safety Interlock. Logic must be satisfied before any manual CB closures can proceed.
SysChks Inactive DDB #880
AR Sys Checks OK DDB #899
AR Force 3 pole DDB #858
1
Force 3Pole Trip DDB #533
Aid 1 Chan Fail DDB #317
Aid 2 Chan Fail DDB #318
1
BAR DDB #448
Input L16 DDB #047
Default PSL blocks autoreclose if any aided scheme channel fails.
Power Swing DDB #297
Inhibit WI DDB #458
Page 14

P446 WITH STANDARD CONTACTS PSL 32 STD RELAYS

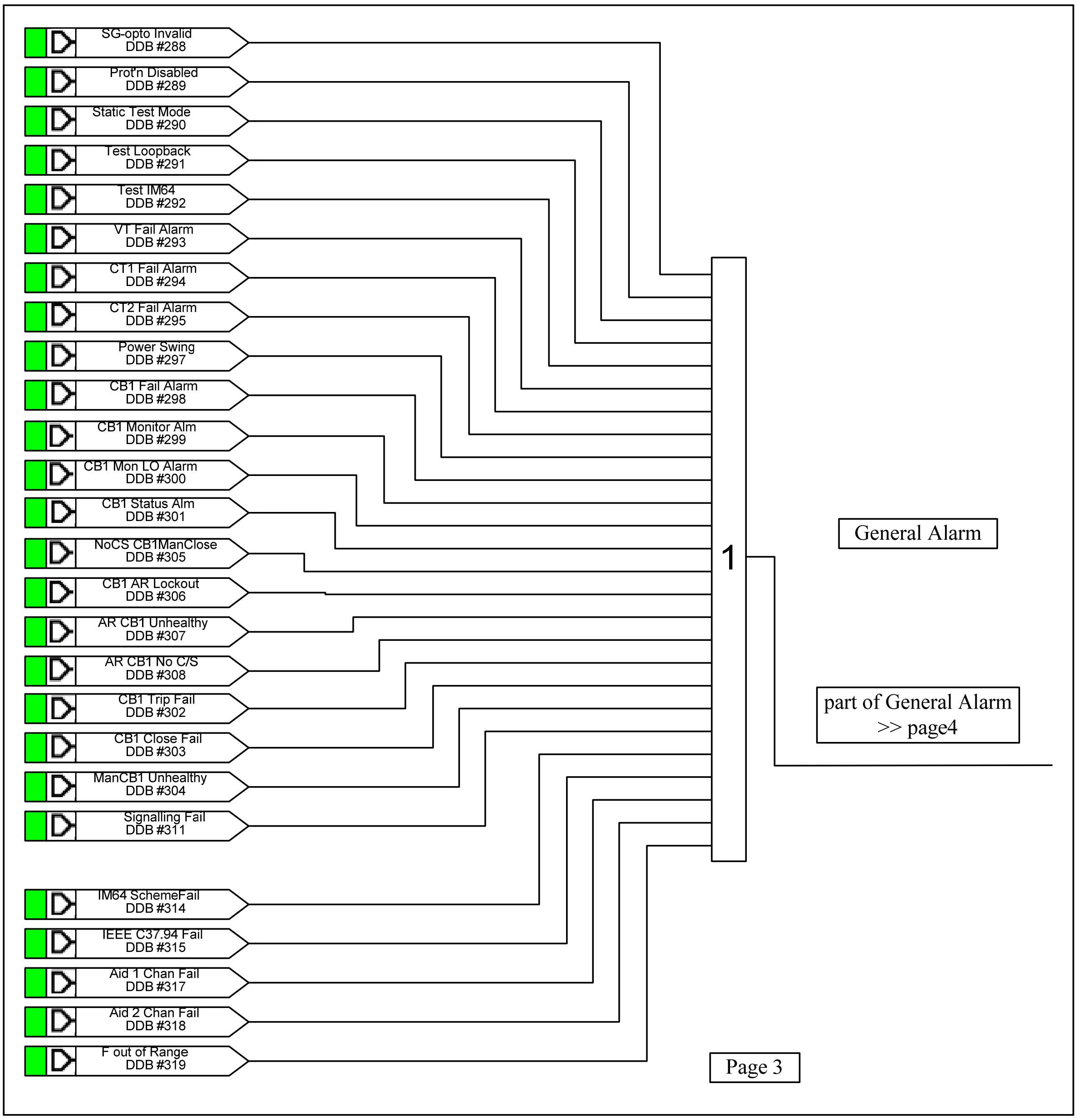
Opto Input Mappings

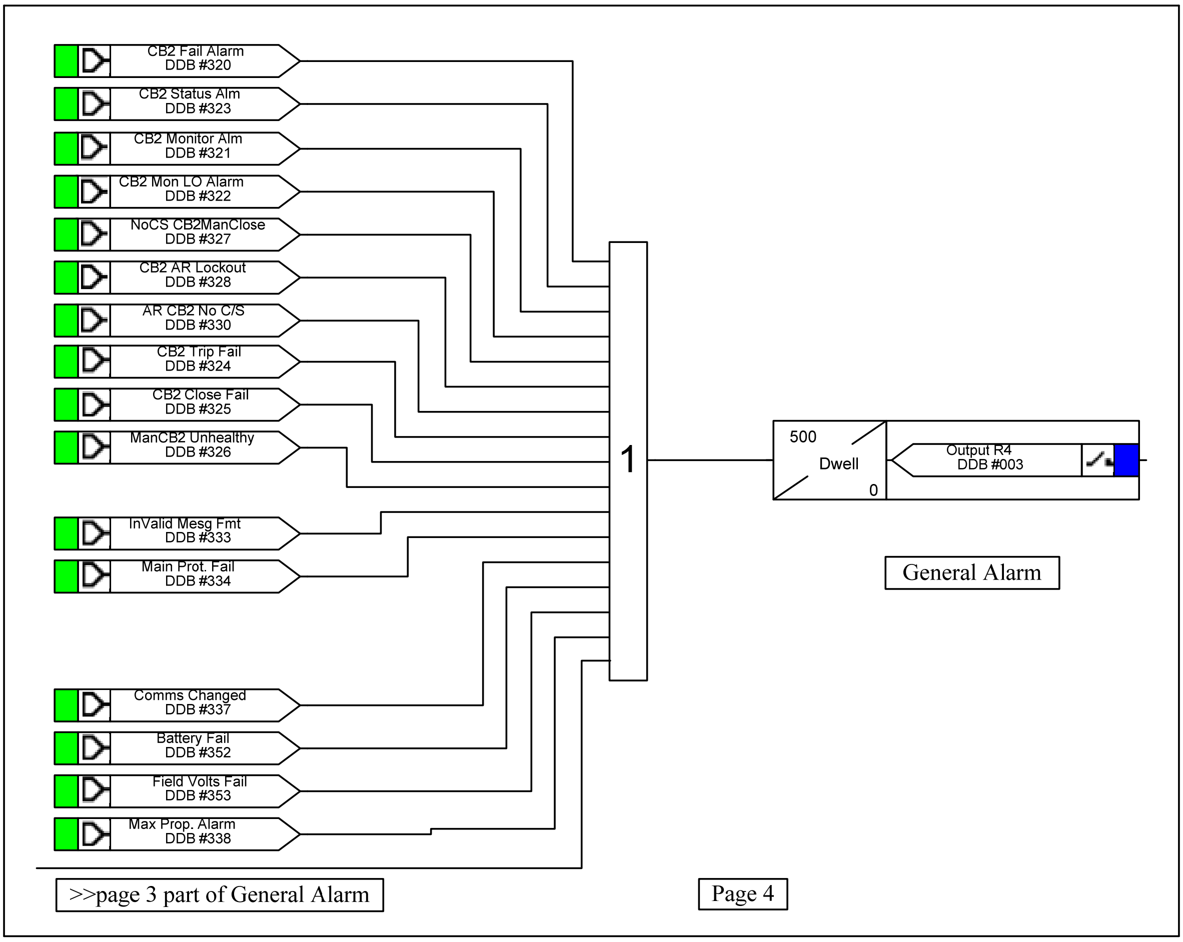

DDB #448
Input L2
DDB #033
Block CB2 AR
DDB #1421
Input L3
DDB #034
Aided1 Scheme Rx
DDB #493
Input L4
DDB #035
Aided 1 COS/LGS
DDB #492
Input L6
DDB #037
CB2 Aux A(52-B)
DDB #433
Input L7
DDB #038
CB2 Aux B(52-B)
DDB #434
Input L8
DDB #039
CB2 Aux C(52-B)
DDB #435
Input L9
DDB #040
CB1Aux A (52-B)
DDB #425
Input L10
DDB #041
CB1Aux B (52-B)
DDB #426
Input L11
DDB #042
CB1Aux C (52-B)
DDB #427
Input L12
DDB #043
MCB/VTS
DDB #438
Input L13
DDB #044
Init Close CB1
DDB #440
Input L14
DDB #045
Init Close CB2
DDB #442
Input L15
DDB #046
CB1 Healthy
DDB #436
Input L16
DDB #047
Rst CB1 Lockout
DDB #446
Rst CB2 Lockout
DDB #1422
Input L17
DDB #048
CB2 Healthy
DDB #437
Input L18
DDB #049
IM64 Ch1 Output1
DDB #112
IM64 Ch2 Output1
DDB #120
Input L19
DDB #050
CB1 Ext Trip A
DDB #535
Input L20
DDB #051
CB1 Ext Trip B
DDB #536
Input L21
DDB #052
CB1 Ext Trip C
DDB #537
Input L22
DDB #053
CB2 Ext Trip A
DDB #539
Input L23
DDB #054
CB2 Ext Trip B
DDB #540
Input L24
DDB #055
CB2 Ext Trip C
DDB #541
Opto L5 can be found on other pages
Page 1

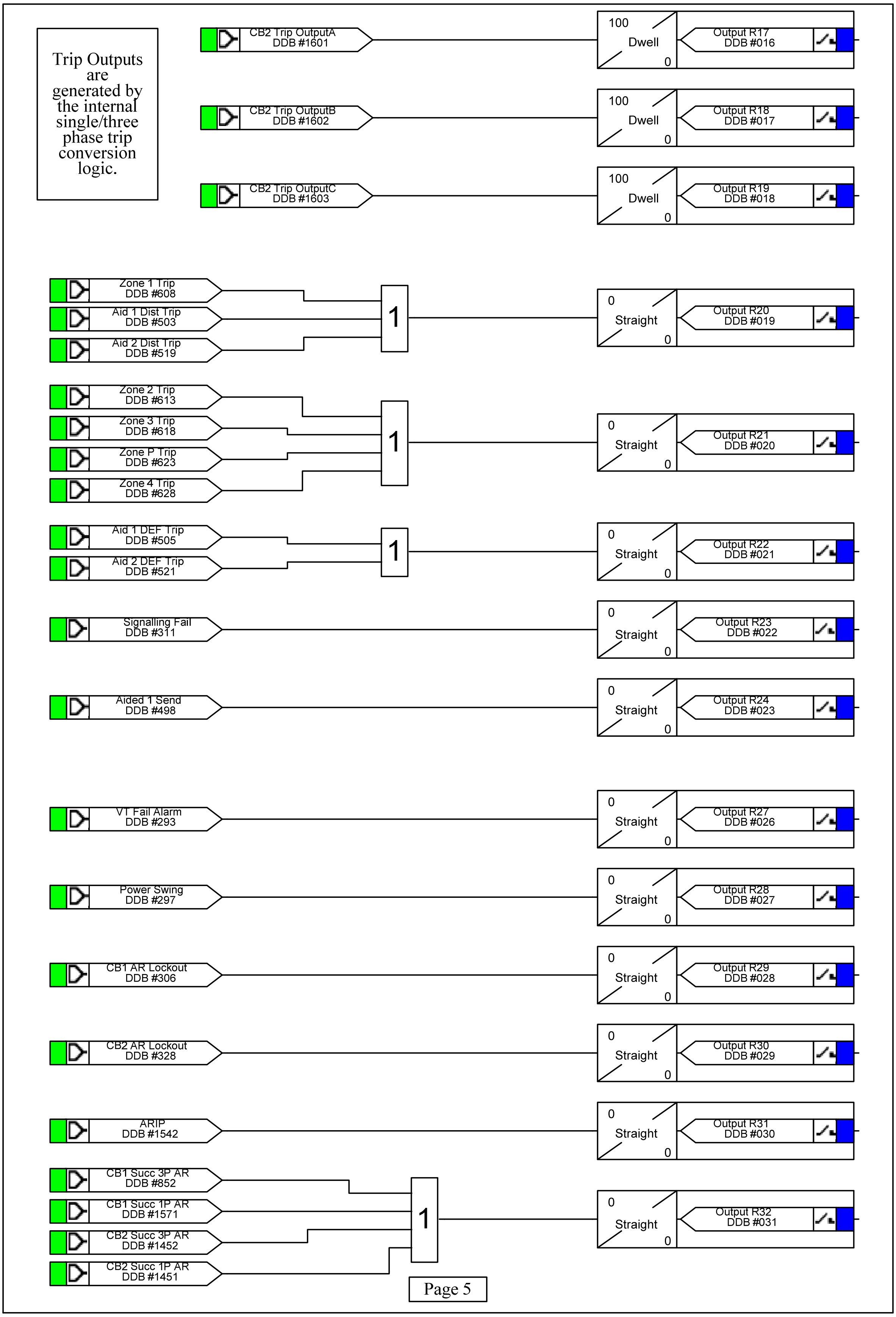
Output Contacts


Zone 1 Trip DDB #608
0 Straight 0
Output R1 DDB #000
Any Trip DDB #522
100 Dwell 0
Output R3 DDB #002
IM64 Ch1 Input 1 DDB #096
IM64 Ch2 Input 1 DDB #104
1
0 Straight 0
Output R5 DDB #004
CB1 Fail1 Trip DDB #834
100 Dwell 0
Output R6 DDB #005
Control CloseCB1 DDB #839
0 Straight 0
Output R7 DDB #006
Control TripCB1 DDB #838
0 Straight 0
Output R8 DDB #007
CB1 Trip OutputA DDB #523
100 Dwell 0
Output R9 DDB #008
CB1 Trip OutputB DDB #524
100 Dwell 0
Output R10 DDB #009
CB1 Trip OutputC DDB #525
100 Dwell 0
Output R11 DDB #010
CB2 Fail1 Trip DDB #836
100 Dwell 0
Output R12 DDB #011
Control CloseCB2 DDB #841
0 Straight 0
Output R13 DDB #012
Control TripCB2 DDB #840
0 Straight 0
Output R14 DDB #013
CB1 Fail2 Trip DDB #835
100 Dwell 0
Output R15 DDB #014
CB2 Fail2 Trip DDB #837
100 Dwell 0
Output R16 DDB #015
Page 2

Trip Outputs are generated by the internal single/three phase trip conversion logic.

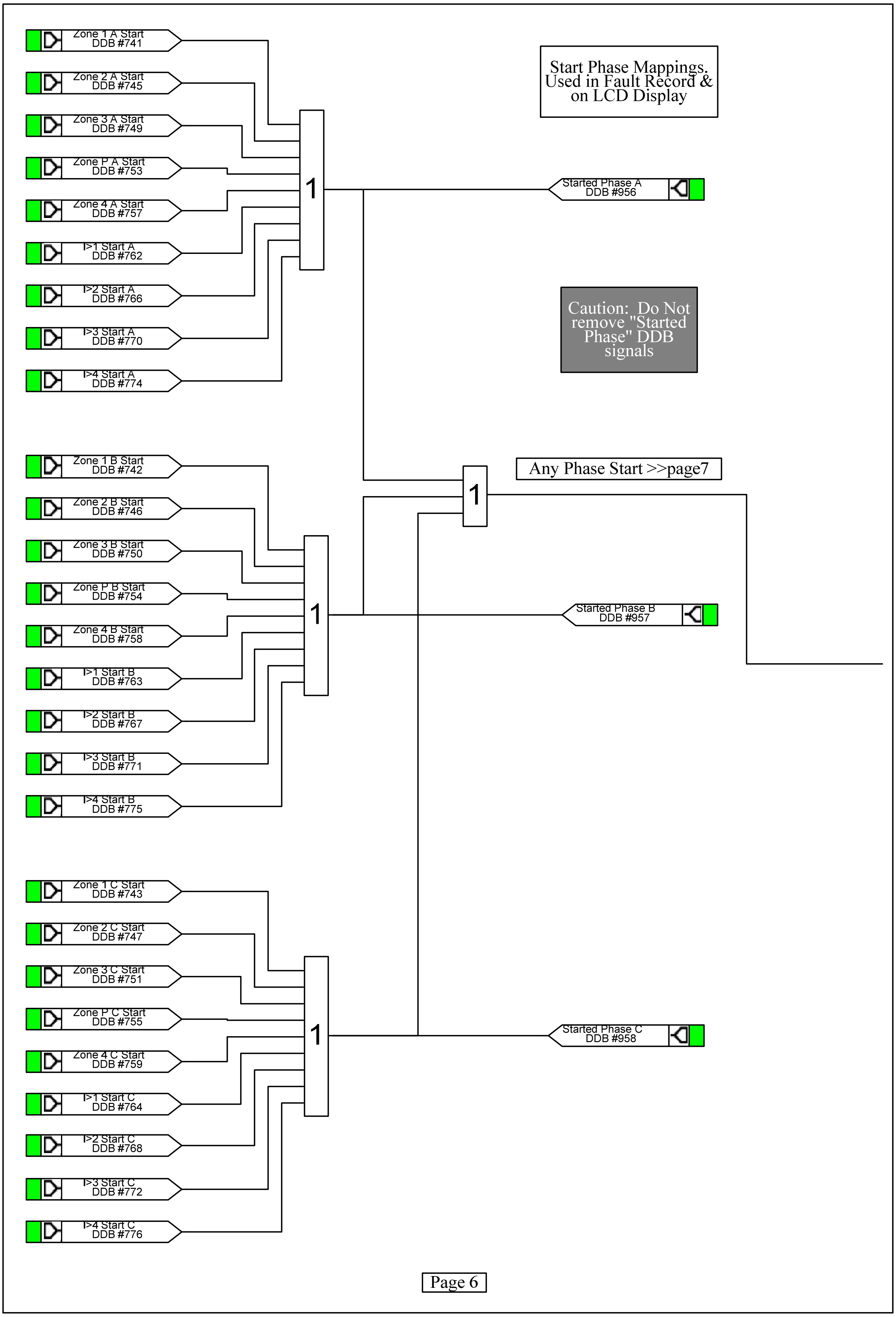

SG-opto Invalid
DDB #288
Prot'n Disabled
DDB #289
Static Test Mode
DDB #290
Test Loopback
DDB #291
Test IM64
DDB #292
VT Fail Alarm
DDB #293
CT1 Fail Alarm
DDB #294
CT2 Fail Alarm
DDB #295
Power Swing
DDB #297
CB1 Fail Alarm
DDB #298
CB1 Monitor Alm
DDB #299
CB1 Mon LO Alarm
DDB #300
CB1 Status Alm
DDB #301
NoCS CB1ManClose
DDB #305
CB1 AR Lockout
DDB #306
AR CB1 Unhealthy
DDB #307
AR CB1 No C/S
DDB #308
CB1 Trip Fail
DDB #302
CB1 Close Fail
DDB #303
ManCB1 Unhealthy
DDB #304
Signalling Fail
DDB #311
IM64 SchemeFail
DDB #314
IEEE C37.94 Fail
DDB #315
Aid 1 Chan Fail
DDB #317
Aid 2 Chan Fail
DDB #318
F out of Range
DDB #319
1
General Alarm
part of General Alarm
>> page4
Page 3

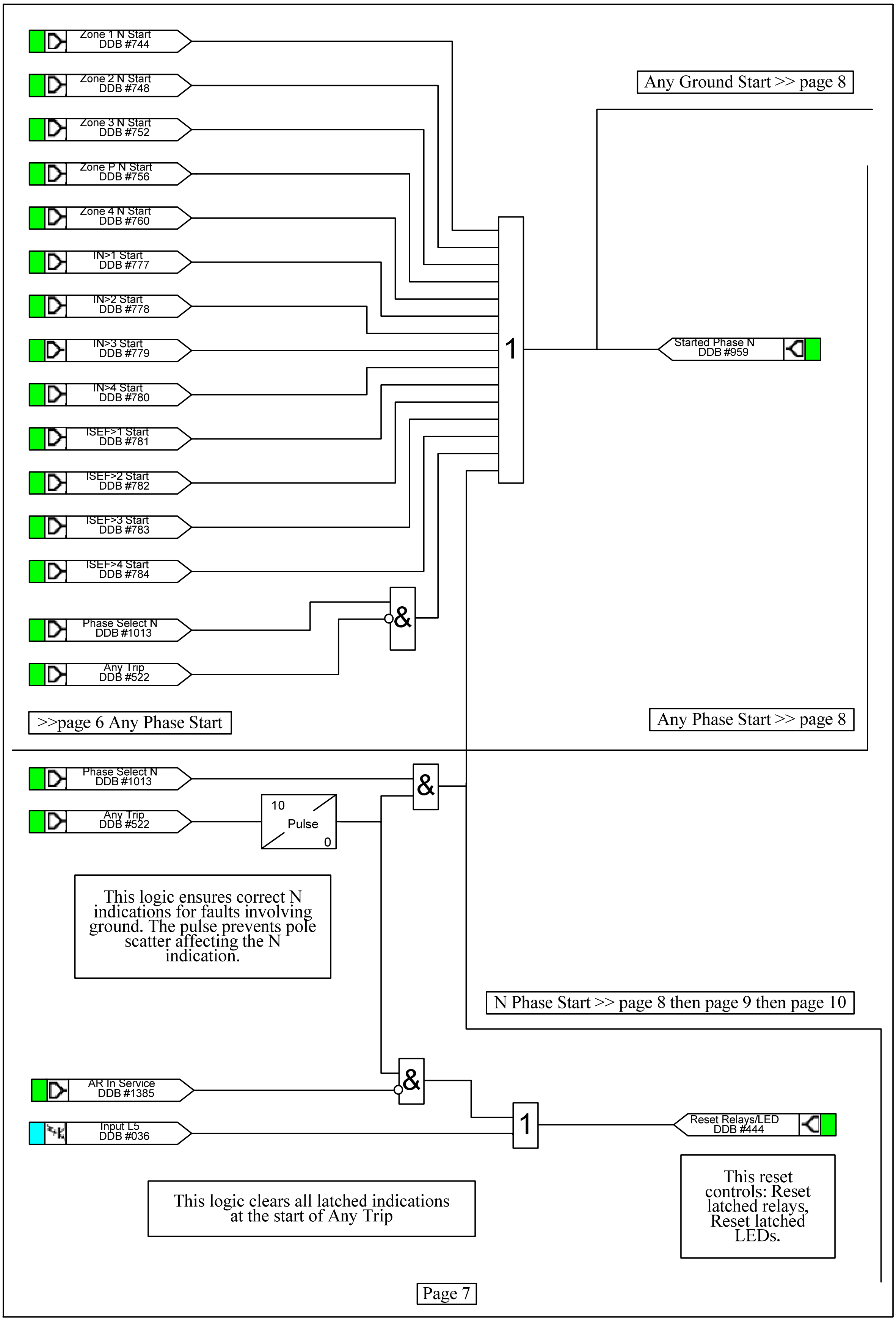

CB2 Fail Alarm
DDB #320
CB2 Status Alm
DDB #323
CB2 Monitor Alm
DDB #321
CB2 Mon LO Alarm
DDB #322
NoCS CB2ManClose
DDB #327
CB2 AR Lockout
DDB #328
AR CB2 No C/S
DDB #330
CB2 Trip Fail
DDB #324
CB2 Close Fail
DDB #325
ManCB2 Unhealthy
DDB #326
InValid Mesg Fmt
DDB #333
Main Prot. Fail
DDB #334
Comms Changed
DDB #337
Battery Fail
DDB #352
Field Volts Fail
DDB #353
Max Prop. Alarm
DDB #338
1
500
Dwell
0
Output R4
DDB #003
General Alarm
>>page 3 part of General Alarm
Page 4



Trip Outputs are generated by the internal single/three phase trip conversion logic.

CB2 Trip OutputA DDB #1601
100 Dwell 0
Output R17 DDB #016
CB2 Trip OutputB DDB #1602
100 Dwell 0
Output R18 DDB #017
CB2 Trip OutputC DDB #1603
100 Dwell 0
Output R19 DDB #018
Zone 1 Trip DDB #608
Aid 1 Dist Trip DDB #503
Aid 2 Dist Trip DDB #519
1
0 Straight 0
Output R20 DDB #019
Zone 2 Trip DDB #613
Zone 3 Trip DDB #618
Zone P Trip DDB #623
Zone 4 Trip DDB #628
1
0 Straight 0
Output R21 DDB #020
Aid 1 DEF Trip DDB #505
Aid 2 DEF Trip DDB #521
1
0 Straight 0
Output R22 DDB #021
Signalling Fail DDB #311
0 Straight 0
Output R23 DDB #022
Aided 1 Send DDB #498
0 Straight 0
Output R24 DDB #023
VT Fail Alarm DDB #293
0 Straight 0
Output R27 DDB #026
Power Swing DDB #297
0 Straight 0
Output R28 DDB #027
CB1 AR Lockout DDB #306
0 Straight 0
Output R29 DDB #028
CB2 AR Lockout DDB #328
0 Straight 0
Output R30 DDB #029
ARIP DDB #1542
0 Straight 0
Output R31 DDB #030
CB1 Succ 3P AR DDB #852
CB1 Succ 1P AR DDB #1571
CB2 Succ 3P AR DDB #1452
CB2 Succ 1P AR DDB #1451
1
0 Straight 0
Output R32 DDB #031
Page 5

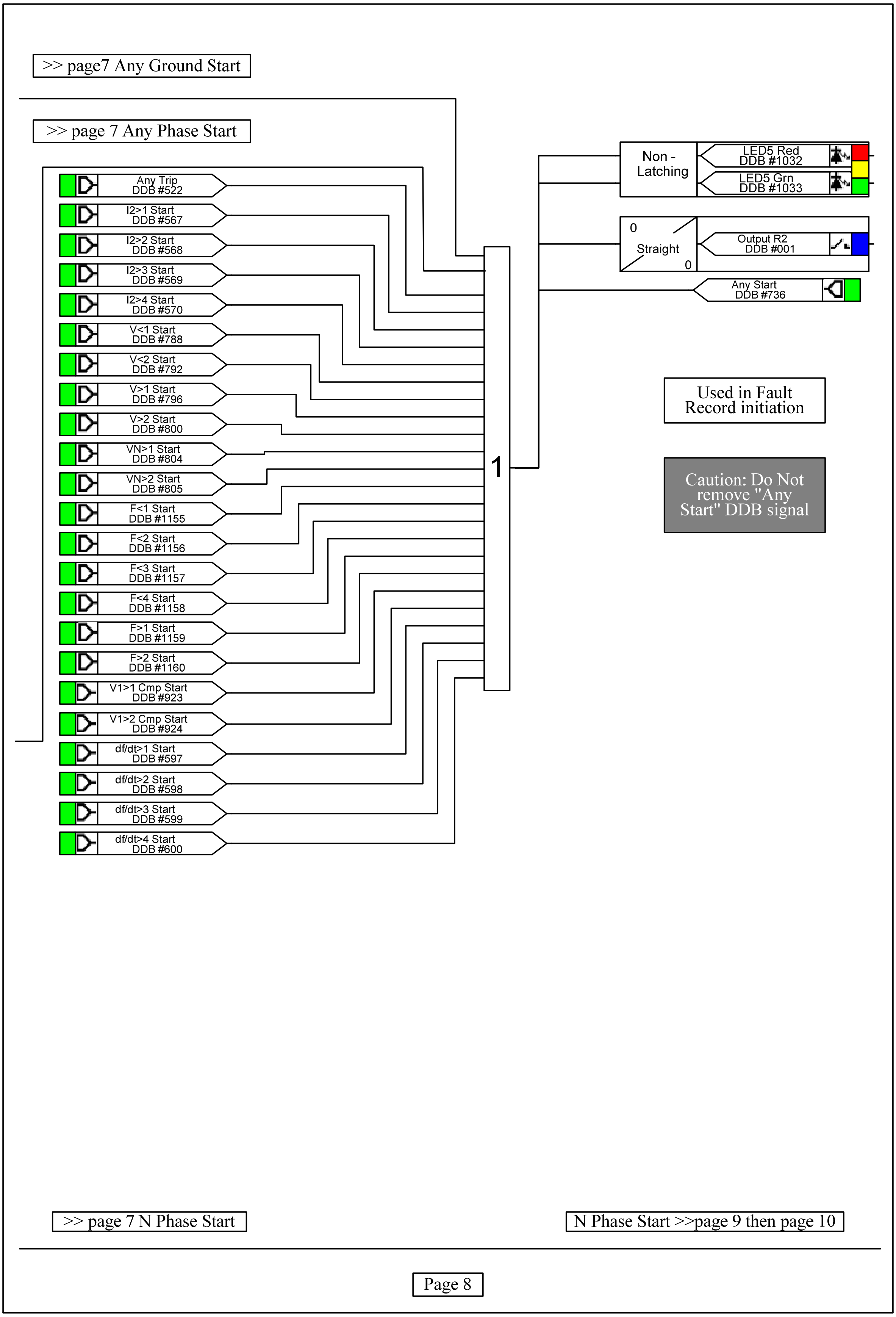

Zone 1 A Start DDB #741
Zone 2 A Start DDB #745
Zone 3 A Start DDB #749
Zone P A Start DDB #753
Zone 4 A Start DDB #757
I>1 Start A DDB #762
I>2 Start A DDB #766
I>3 Start A DDB #770
I>4 Start A DDB #774
1
Started Phase A DDB #956
Start Phase Mappings. Used in Fault Record & on LCD Display
Caution: Do Not remove "Started Phase" DDB signals
Zone 1 B Start DDB #742
Zone 2 B Start DDB #746
Zone 3 B Start DDB #750
Zone P B Start DDB #754
Zone 4 B Start DDB #758
I>1 Start B DDB #763
I>2 Start B DDB #767
I>3 Start B DDB #771
I>4 Start B DDB #775
1
Any Phase Start >>page7
1
Started Phase B DDB #957
Zone 1 C Start DDB #743
Zone 2 C Start DDB #747
Zone 3 C Start DDB #751
Zone P C Start DDB #755
Zone 4 C Start DDB #759
I>1 Start C DDB #764
I>2 Start C DDB #768
I>3 Start C DDB #772
I>4 Start C DDB #776
1
Started Phase C DDB #958
Page 6

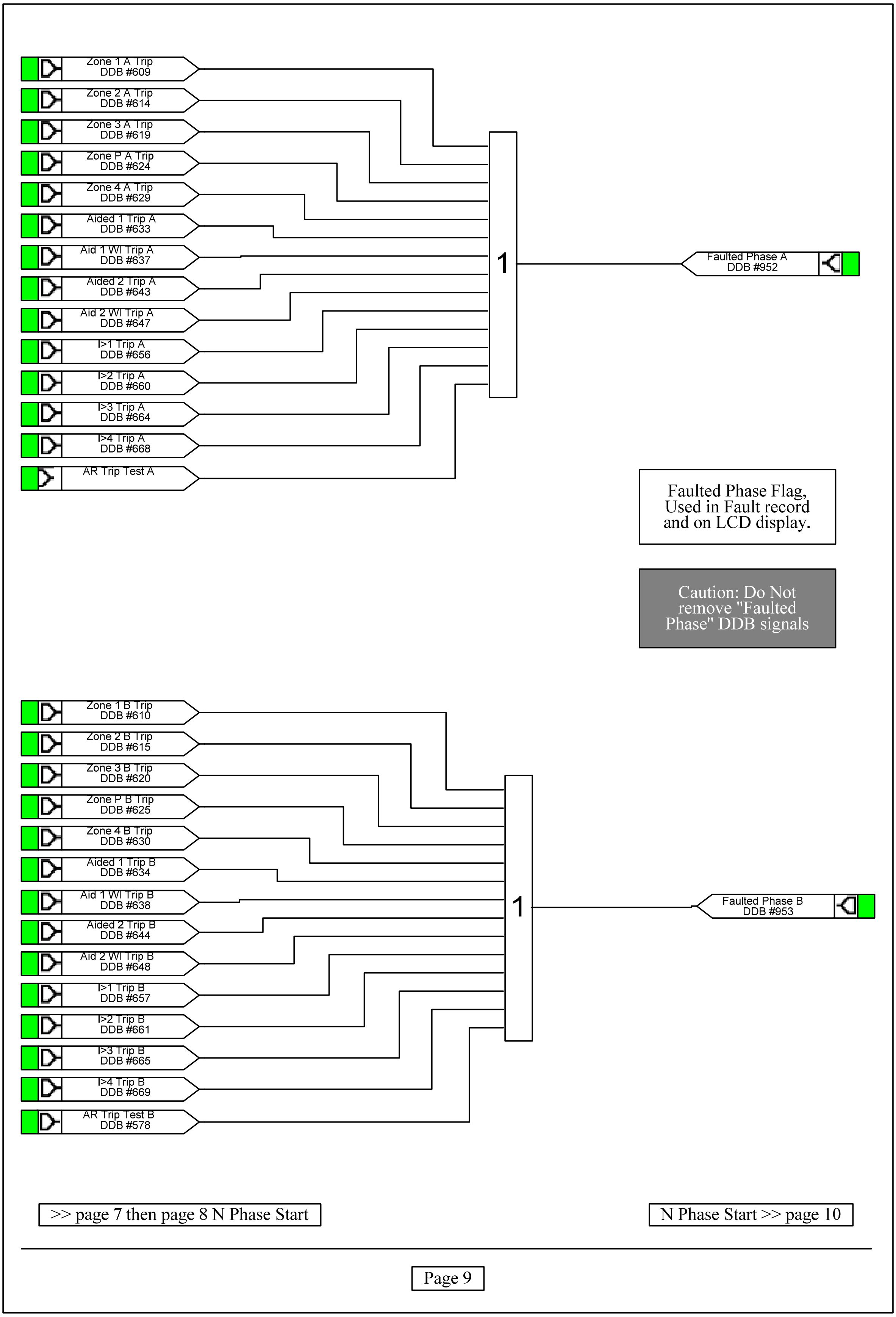

Zone 1 N Start
DDB #744
Zone 2 N Start
DDB #748
Zone 3 N Start
DDB #752
Zone P N Start
DDB #756
Zone 4 N Start
DDB #760
IN>1 Start
DDB #777
IN>2 Start
DDB #778
IN>3 Start
DDB #779
IN>4 Start
DDB #780
ISEF>1 Start
DDB #781
ISEF>2 Start
DDB #782
ISEF>3 Start
DDB #783
ISEF>4 Start
DDB #784
Phase Select N
DDB #1013
Any Trip
DDB #522
&
1
Any Ground Start >> page 8
Started Phase N
DDB #959
>>page 6 Any Phase Start
Any Phase Start >> page 8
Phase Select N
DDB #1013
Any Trip
DDB #522
10
Pulse
0
&
N Phase Start >> page 8 then page 9 then page 10
AR In Service
DDB #1385
Input L5
DDB #036
&
1
Reset Relays/LED
DDB #444
Page 7

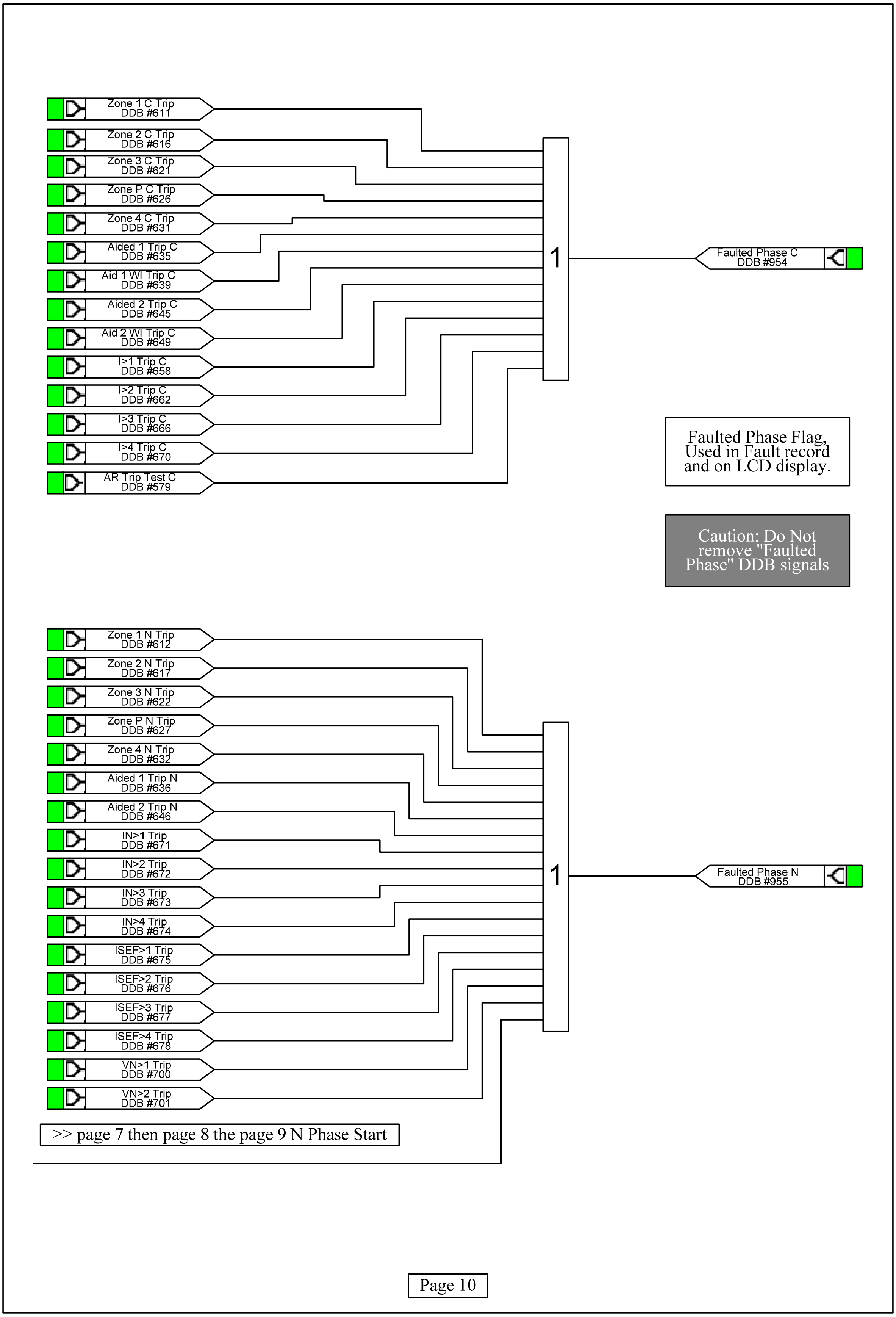
This logic ensures correct N indications for faults involving ground. The pulse prevents pole scatter affecting the N indication.

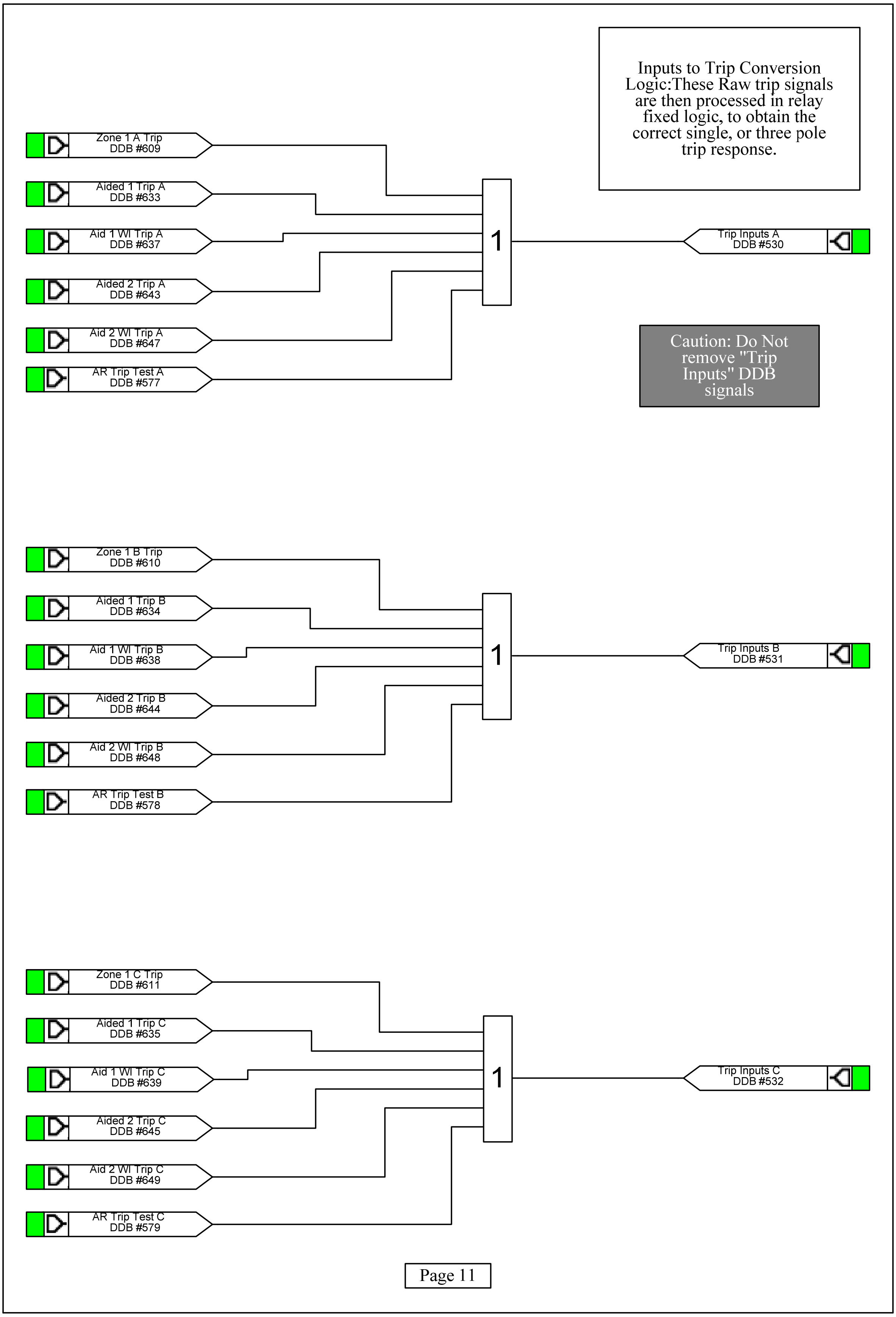
This logic clears all latched indications at the start of Any Trip

This reset controls: Reset latched relays, Reset latched LEDs.


>> page7 Any Ground Start
>> page 7 Any Phase Start
Any Trip DDB #522
I2>1 Start DDB #567
I2>2 Start DDB #568
I2>3 Start DDB #569
I2>4 Start DDB #570
V<1 Start DDB #788
V<2 Start DDB #792
V>1 Start DDB #796
V>2 Start DDB #800
VN>1 Start DDB #804
VN>2 Start DDB #805
F<1 Start DDB #1155
F<2 Start DDB #1156
F<3 Start DDB #1157
F<4 Start DDB #1158
F>1 Start DDB #1159
F>2 Start DDB #1160
V1>1 Cmp Start DDB #923
V1>2 Cmp Start DDB #924
df/dt>1 Start DDB #597
df/dt>2 Start DDB #598
df/dt>3 Start DDB #599
df/dt>4 Start DDB #600
1
Non - Latching
LED5 Red DDB #1032
LED5 Grn DDB #1033
0
Straight
0
Output R2 DDB #001
Any Start DDB #736
Used in Fault Record initiation
Caution: Do Not remove "Any Start" DDB signal
>> page 7 N Phase Start
N Phase Start >>page 9 then page 10
Page 8

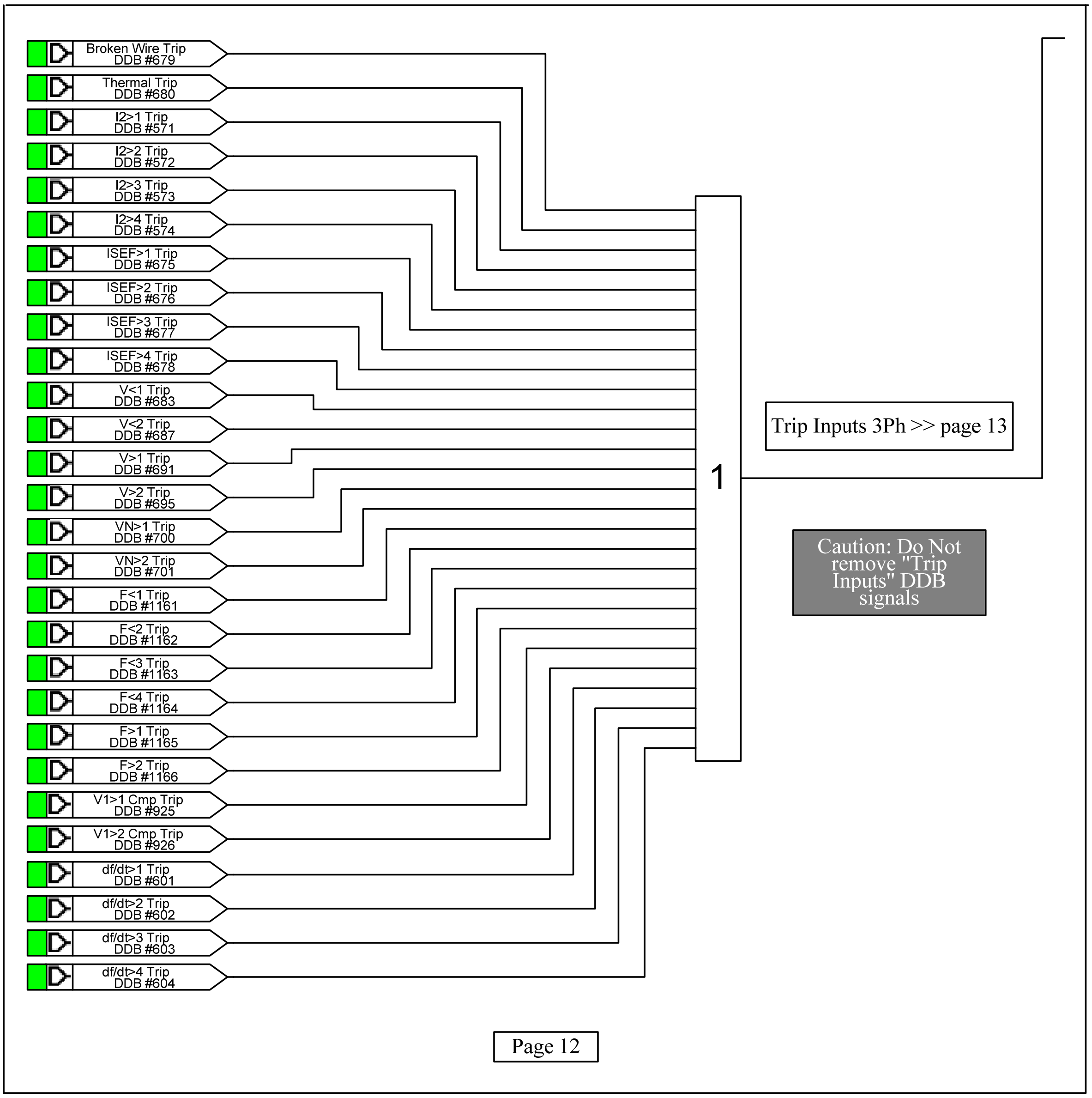

Zone 1 A Trip
DDB #609
Zone 2 A Trip
DDB #614
Zone 3 A Trip
DDB #619
Zone P A Trip
DDB #624
Zone 4 A Trip
DDB #629
Aided 1 Trip A
DDB #633
Aid 1 WI Trip A
DDB #637
Aided 2 Trip A
DDB #643
Aid 2 WI Trip A
DDB #647
I>1 Trip A
DDB #656
I>2 Trip A
DDB #660
I>3 Trip A
DDB #664
I>4 Trip A
DDB #668
AR Trip Test A
1
Faulted Phase A
DDB #952
Faulted Phase Flag, Used in Fault record and on LCD display.
Caution: Do Not remove "Faulted Phase" DDB signals
Zone 1 B Trip
DDB #610
Zone 2 B Trip
DDB #615
Zone 3 B Trip
DDB #620
Zone P B Trip
DDB #625
Zone 4 B Trip
DDB #630
Aided 1 Trip B
DDB #634
Aid 1 WI Trip B
DDB #638
Aided 2 Trip B
DDB #644
Aid 2 WI Trip B
DDB #648
I>1 Trip B
DDB #657
I>2 Trip B
DDB #661
I>3 Trip B
DDB #665
I>4 Trip B
DDB #669
AR Trip Test B
DDB #578
1
Faulted Phase B
DDB #953
>> page 7 then page 8 N Phase Start
N Phase Start >> page 10
Page 9

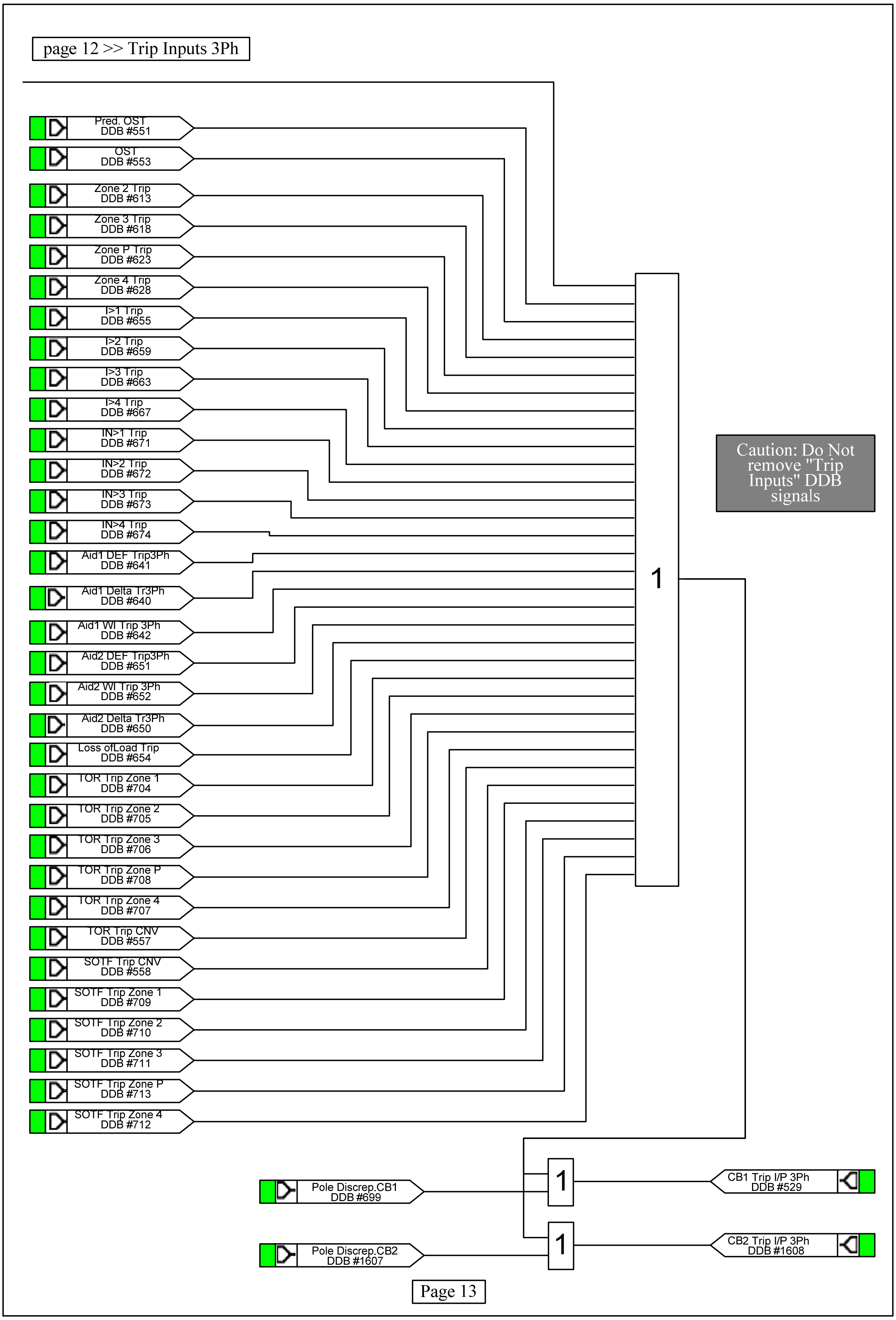

Zone 1 C Trip DDB #611
Zone 2 C Trip DDB #616
Zone 3 C Trip DDB #621
Zone P C Trip DDB #626
Zone 4 C Trip DDB #631
Aided 1 Trip C DDB #635
Aid 1 WI Trip C DDB #639
Aided 2 Trip C DDB #645
Aid 2 WI Trip C DDB #649
I>1 Trip C DDB #658
I>2 Trip C DDB #662
I>3 Trip C DDB #666
I>4 Trip C DDB #670
AR Trip Test C DDB #579
1
Faulted Phase C DDB #954
Faulted Phase Flag, Used in Fault record and on LCD display.
Caution: Do Not remove "Faulted Phase" DDB signals
Zone 1 N Trip DDB #612
Zone 2 N Trip DDB #617
Zone 3 N Trip DDB #622
Zone P N Trip DDB #627
Zone 4 N Trip DDB #632
Aided 1 Trip N DDB #636
Aided 2 Trip N DDB #646
IN>1 Trip DDB #671
IN>2 Trip DDB #672
IN>3 Trip DDB #673
IN>4 Trip DDB #674
ISEF>1 Trip DDB #675
ISEF>2 Trip DDB #676
ISEF>3 Trip DDB #677
ISEF>4 Trip DDB #678
VN>1 Trip DDB #700
VN>2 Trip DDB #701
1
Faulted Phase N DDB #955
>> page 7 then page 8 the page 9 N Phase Start
Page 10

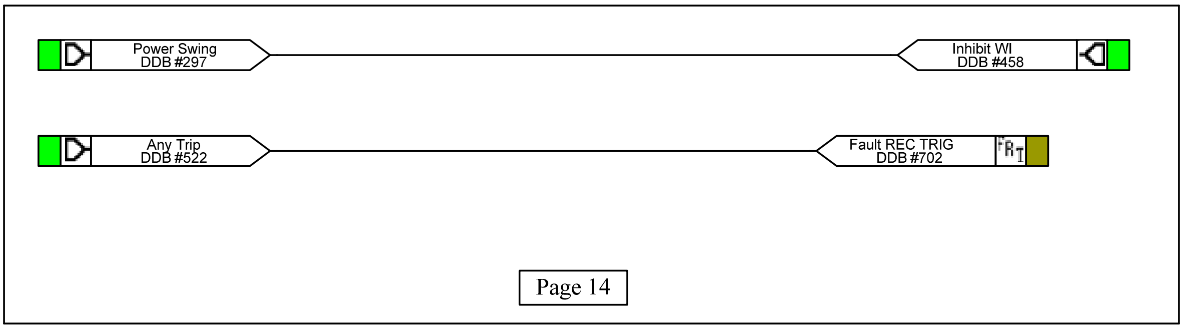

Inputs to Trip Conversion Logic:These Raw trip signals are then processed in relay fixed logic, to obtain the correct single, or three pole trip response.

Caution: Do Not remove "Trip Inputs" DDB signals

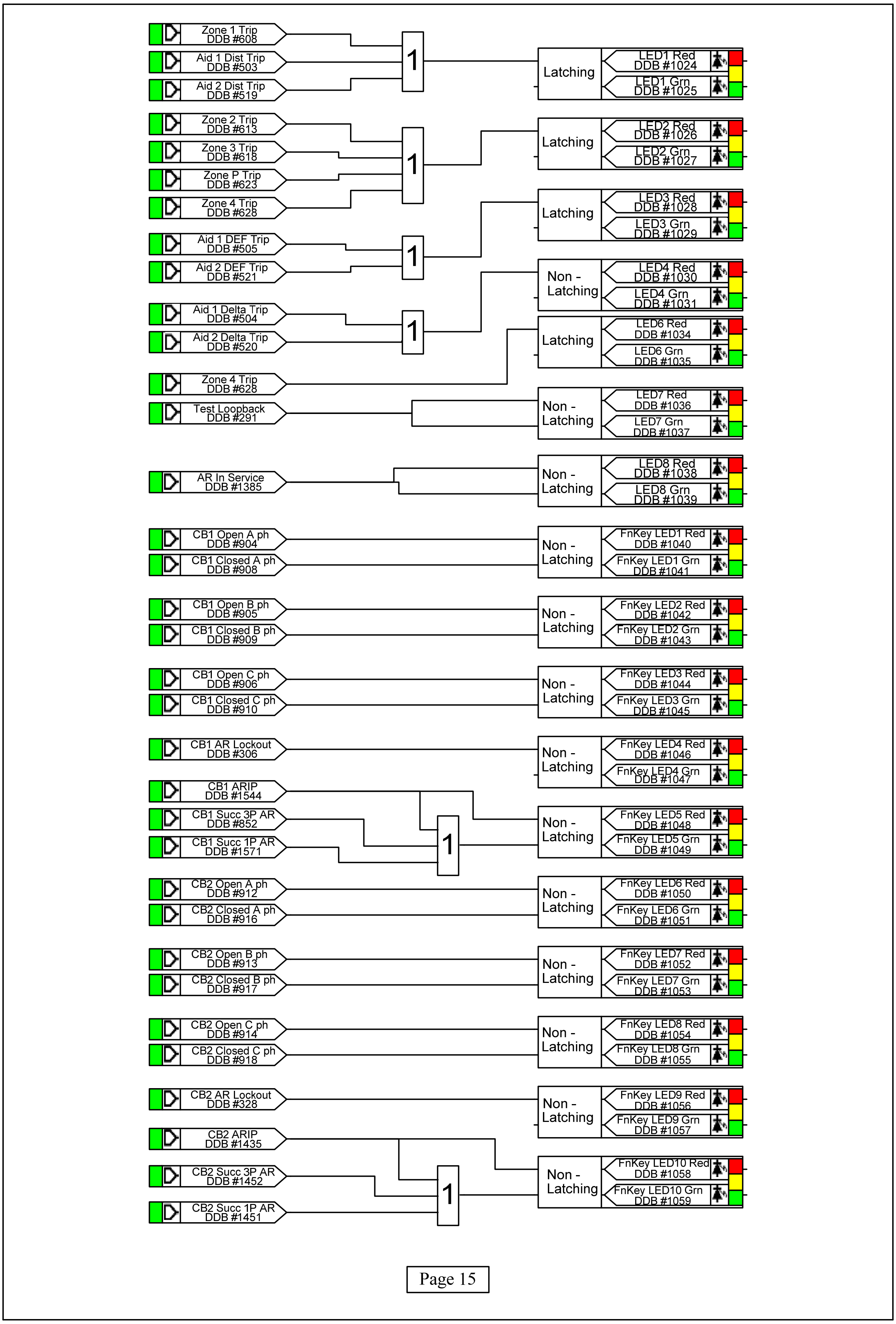
Zone 1 A Trip DDB #609
Aided 1 Trip A DDB #633
Aid 1 WI Trip A DDB #637
Aided 2 Trip A DDB #643
Aid 2 WI Trip A DDB #647
AR Trip Test A DDB #577
1
Trip Inputs A DDB #530
Zone 1 B Trip DDB #610
Aided 1 Trip B DDB #634
Aid 1 WI Trip B DDB #638
Aided 2 Trip B DDB #644
Aid 2 WI Trip B DDB #648
AR Trip Test B DDB #578
1
Trip Inputs B DDB #531
Zone 1 C Trip DDB #611
Aided 1 Trip C DDB #635
Aid 1 WI Trip C DDB #639
Aided 2 Trip C DDB #645
Aid 2 WI Trip C DDB #649
AR Trip Test C DDB #579
1
Trip Inputs C DDB #532
Page 11


Broken Wire Trip DDB #679
Thermal Trip DDB #680
I2>1 Trip DDB #571
I2>2 Trip DDB #572
I2>3 Trip DDB #573
I2>4 Trip DDB #574
ISEF>1 Trip DDB #675
ISEF>2 Trip DDB #676
ISEF>3 Trip DDB #677
ISEF>4 Trip DDB #678
V<1 Trip DDB #683
V<2 Trip DDB #687
V>1 Trip DDB #691
V>2 Trip DDB #695
VN>1 Trip DDB #700
VN>2 Trip DDB #701
F<1 Trip DDB #1161
F<2 Trip DDB #1162
F<3 Trip DDB #1163
F<4 Trip DDB #1164
F>1 Trip DDB #1165
F>2 Trip DDB #1166
V1>1 Cmp Trip DDB #925
V1>2 Cmp Trip DDB #926
df/dt>1 Trip DDB #601
df/dt>2 Trip DDB #602
df/dt>3 Trip DDB #603
df/dt>4 Trip DDB #604
1
Trip Inputs 3Ph >> page 13
Caution: Do Not remove "Trip Inputs" DDB signals
Page 12


page 12 >> Trip Inputs 3Ph
Pred. OST DDB #551
OST DDB #553
Zone 2 Trip DDB #613
Zone 3 Trip DDB #618
Zone P Trip DDB #623
Zone 4 Trip DDB #628
I>1 Trip DDB #655
I>2 Trip DDB #659
I>3 Trip DDB #663
I>4 Trip DDB #667
IN>1 Trip DDB #671
IN>2 Trip DDB #672
IN>3 Trip DDB #673
IN>4 Trip DDB #674
Aid1 DEF Trip3Ph DDB #641
Aid1 Delta Tr3Ph DDB #640
Aid1 WI Trip 3Ph DDB #642
Aid2 DEF Trip3Ph DDB #651
Aid2 WI Trip 3Ph DDB #652
Aid2 Delta Tr3Ph DDB #650
Loss ofLoad Trip DDB #654
TOR Trip Zone 1 DDB #704
TOR Trip Zone 2 DDB #705
TOR Trip Zone 3 DDB #706
TOR Trip Zone P DDB #708
TOR Trip Zone 4 DDB #707
TOR Trip CNV DDB #557
SOTF Trip CNV DDB #558
SOTF Trip Zone 1 DDB #709
SOTF Trip Zone 2 DDB #710
SOTF Trip Zone 3 DDB #711
SOTF Trip Zone P DDB #713
SOTF Trip Zone 4 DDB #712
1
Caution: Do Not remove "Trip Inputs" DDB signals
Pole Discrep.CB1 DDB #699
Pole Discrep.CB2 DDB #1607
1
1
CB1 Trip I/P 3Ph DDB #529
CB2 Trip I/P 3Ph DDB #1608
Page 13

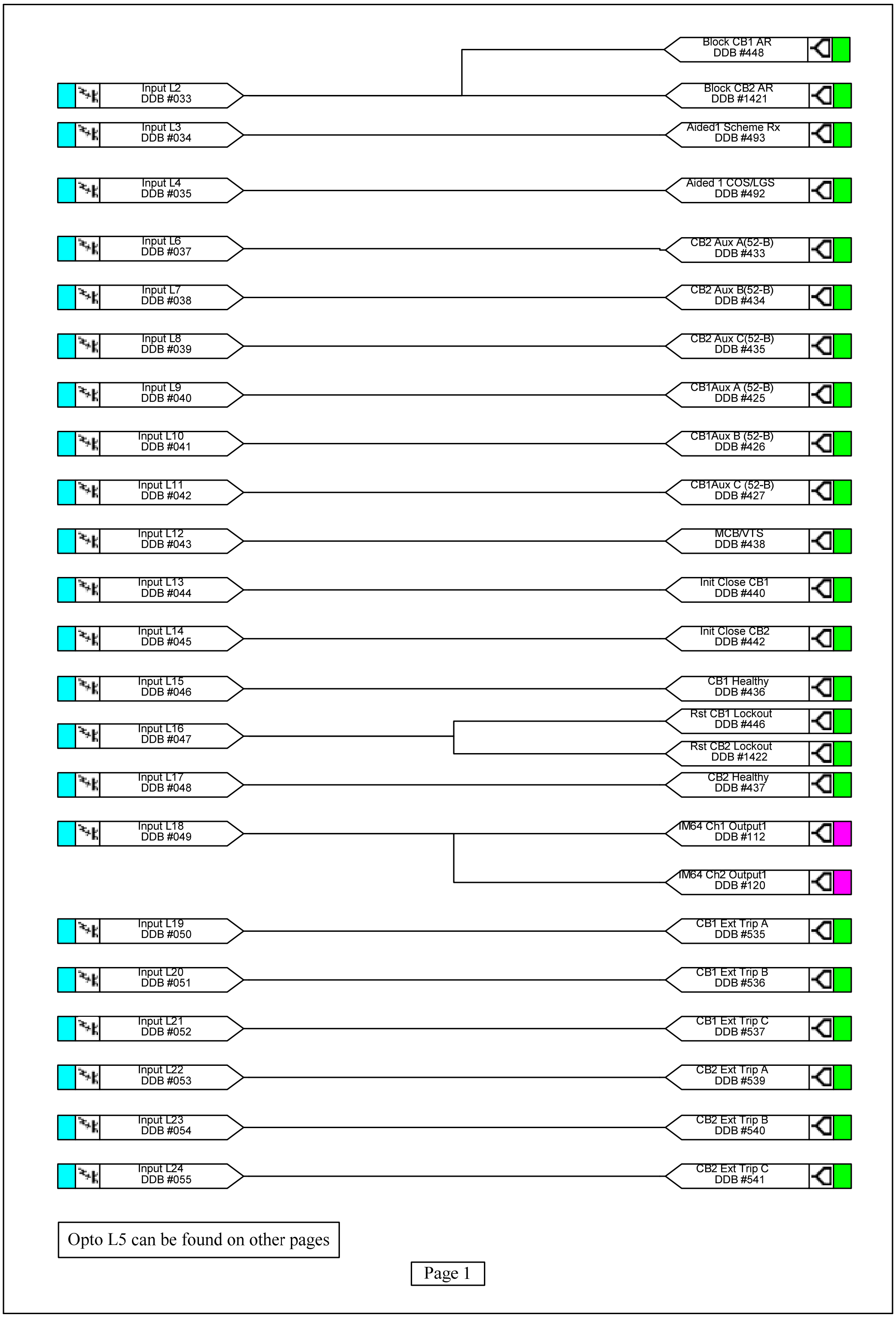

Power Swing
DDB #297
Inhibit WI
DDB #458
Any Trip
DDB #522
Fault REC TRIG
DDB #702
FRT
Page 14

LEDs

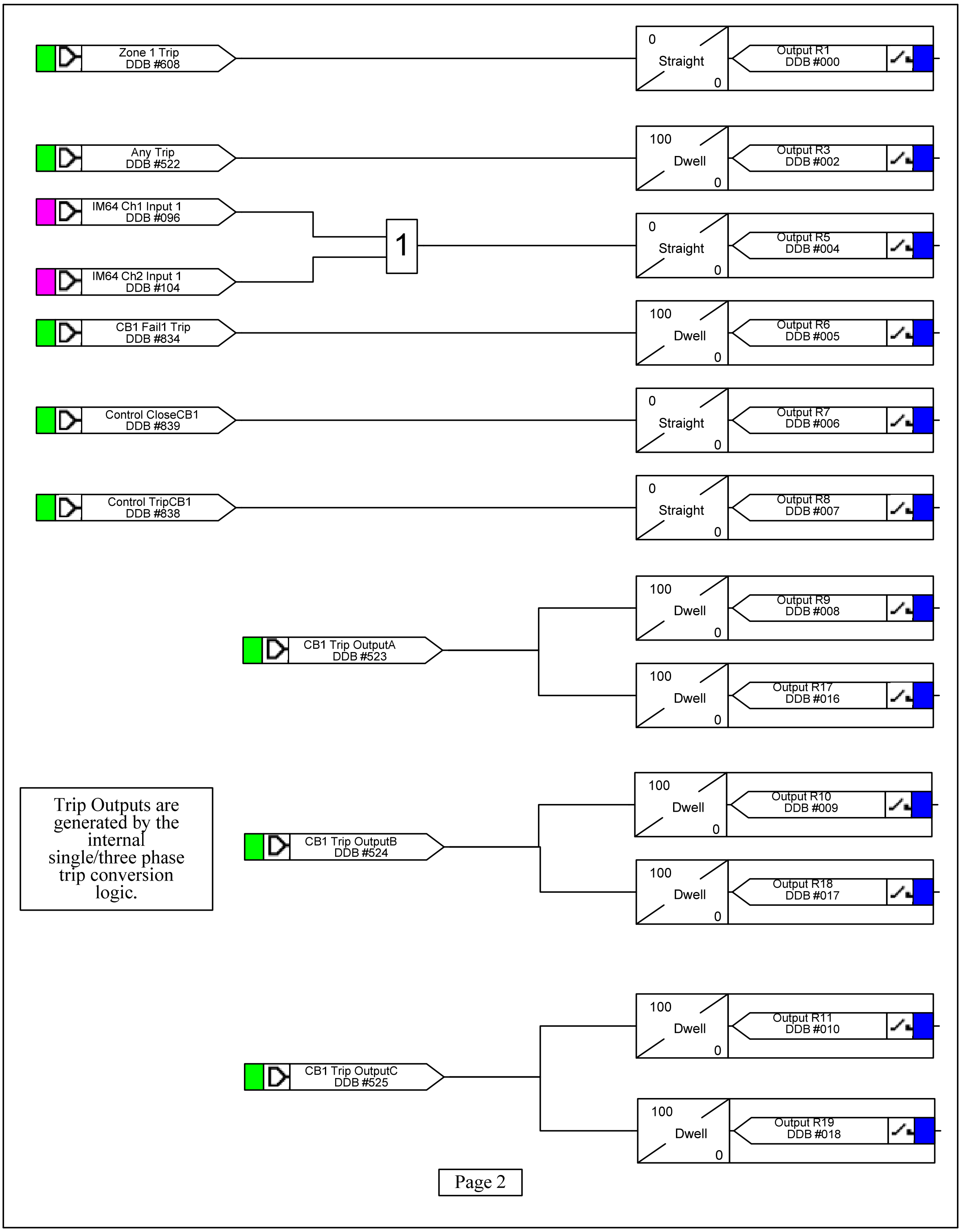

Zone 1 Trip DDB #608
Aid 1 Dist Trip DDB #503
Aid 2 Dist Trip DDB #519
1
Latching
LED1 Red DDB #1024
LED1 Grn DDB #1025
Zone 2 Trip DDB #613
Zone 3 Trip DDB #618
Zone P Trip DDB #623
Zone 4 Trip DDB #628
1
Latching
LED2 Red DDB #1026
LED2 Grn DDB #1027
Aid 1 DEF Trip DDB #505
Aid 2 DEF Trip DDB #521
1
Latching
LED3 Red DDB #1028
LED3 Grn DDB #1029
Aid 1 Delta Trip DDB #504
Aid 2 Delta Trip DDB #520
1
Non - Latching
LED4 Red DDB #1030
LED4 Grn DDB #1031
Zone 4 Trip DDB #628
Latching
LED6 Red DDB #1034
LED6 Grn DDB #1035
Test Loopback DDB #291
Non - Latching
LED7 Red DDB #1036
LED7 Grn DDB #1037
AR In Service DDB #1385
Non - Latching
LED8 Red DDB #1038
LED8 Grn DDB #1039
CB1 Open A ph DDB #904
CB1 Closed A ph DDB #908
Non - Latching
FnKey LED1 Red DDB #1040
FnKey LED1 Grn DDB #1041
CB1 Open B ph DDB #905
CB1 Closed B ph DDB #909
Non - Latching
FnKey LED2 Red DDB #1042
FnKey LED2 Grn DDB #1043
CB1 Open C ph DDB #906
CB1 Closed C ph DDB #910
Non - Latching
FnKey LED3 Red DDB #1044
FnKey LED3 Grn DDB #1045
CB1 AR Lockout DDB #306
Non - Latching
FnKey LED4 Red DDB #1046
FnKey LED4 Grn DDB #1047
CB1 ARIP DDB #1544
CB1 Succ 3P AR DDB #852
CB1 Succ 1P AR DDB #1571
1
Non - Latching
FnKey LED5 Red DDB #1048
FnKey LED5 Grn DDB #1049
CB2 Open A ph DDB #912
CB2 Closed A ph DDB #916
Non - Latching
FnKey LED6 Red DDB #1050
FnKey LED6 Grn DDB #1051
CB2 Open B ph DDB #913
CB2 Closed B ph DDB #917
Non - Latching
FnKey LED7 Red DDB #1052
FnKey LED7 Grn DDB #1053
CB2 Open C ph DDB #914
CB2 Closed C ph DDB #918
Non - Latching
FnKey LED8 Red DDB #1054
FnKey LED8 Grn DDB #1055
CB2 AR Lockout DDB #328
Non - Latching
FnKey LED9 Red DDB #1056
FnKey LED9 Grn DDB #1057
CB2 ARIP DDB #1435
CB2 Succ 3P AR DDB #1452
CB2 Succ 1P AR DDB #1451
1
Non - Latching
FnKey LED10 Red DDB #1058
FnKey LED10 Grn DDB #1059
Page 15

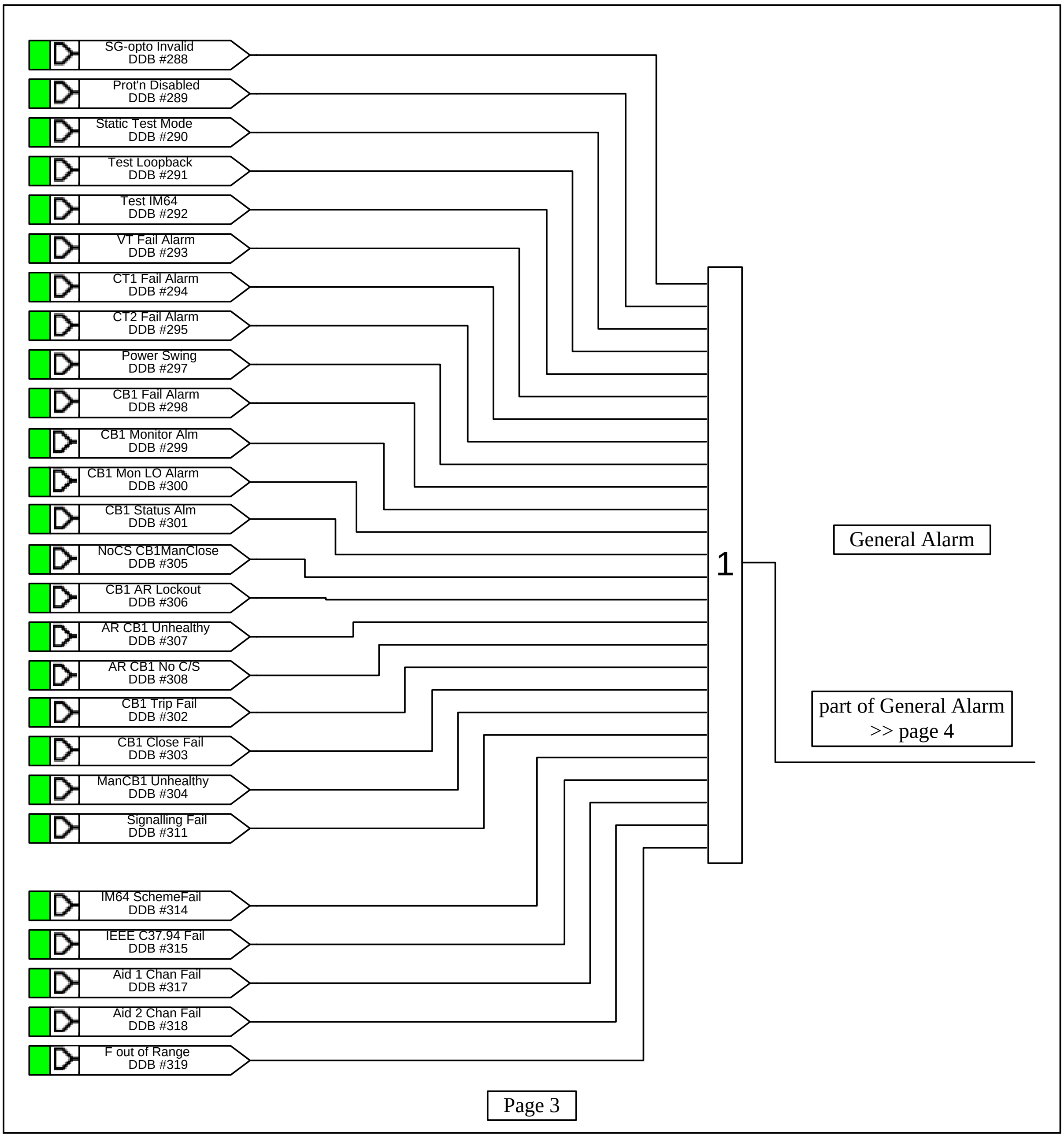
P446 WITH STANDARD CONTACTS PSL 16 STD + 8 HIGH BREAK RELAYS

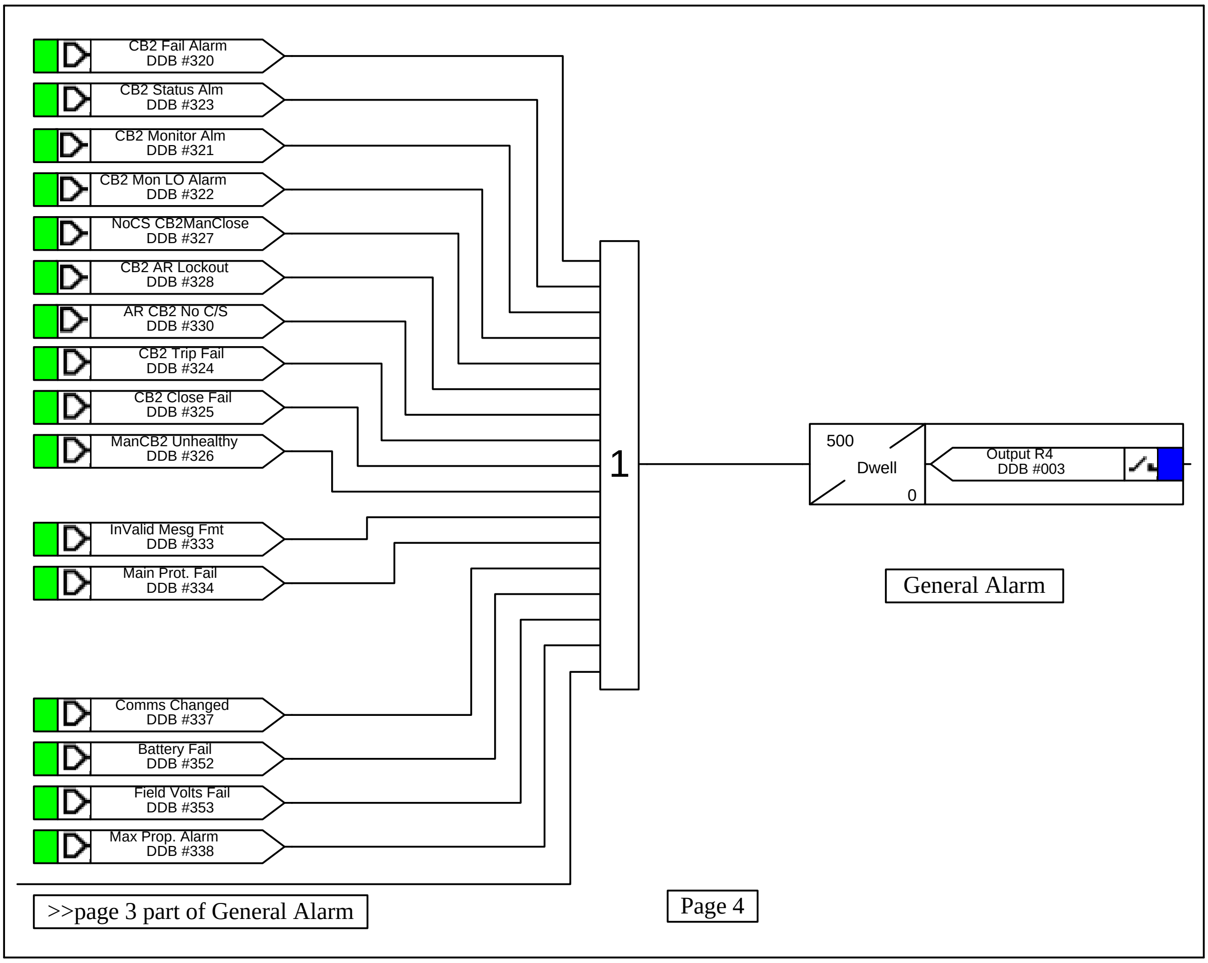
Opto Input Mappings

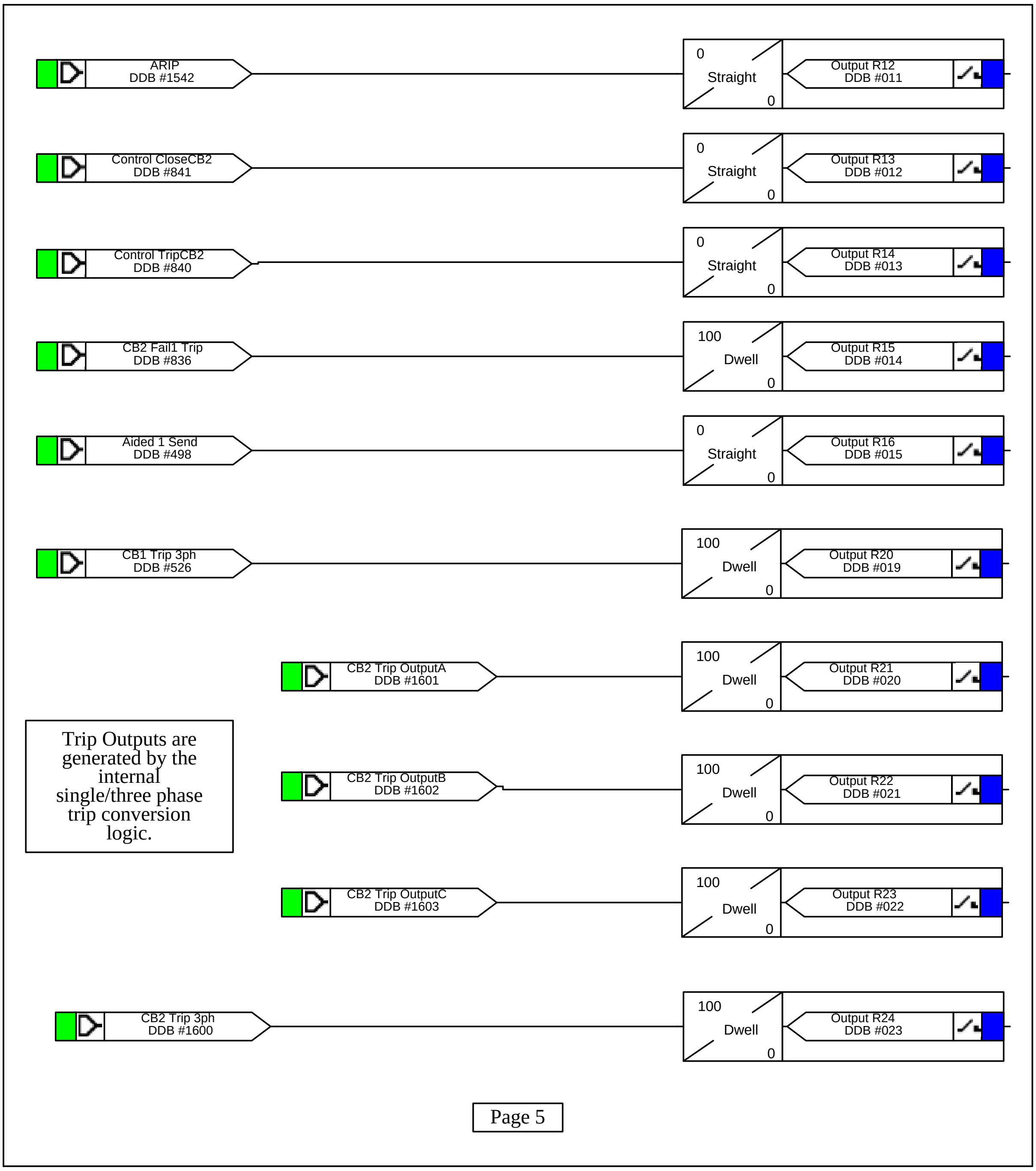

Block CB1 AR DDB #448
Input L2 DDB #033
Block CB2 AR DDB #1421
Input L3 DDB #034
Aided1 Scheme Rx DDB #493
Input L4 DDB #035
Aided 1 COS/LGS DDB #492
Input L6 DDB #037
CB2 Aux A(52-B) DDB #433
Input L7 DDB #038
CB2 Aux B(52-B) DDB #434
Input L8 DDB #039
CB2 Aux C(52-B) DDB #435
Input L9 DDB #040
CB1Aux A (52-B) DDB #425
Input L10 DDB #041
CB1Aux B (52-B) DDB #426
Input L11 DDB #042
CB1Aux C (52-B) DDB #427
Input L12 DDB #043
MCB/VTS DDB #438
Input L13 DDB #044
Init Close CB1 DDB #440
Input L14 DDB #045
Init Close CB2 DDB #442
Input L15 DDB #046
CB1 Healthy DDB #436
Rst CB1 Lockout DDB #446
Input L16 DDB #047
Rst CB2 Lockout DDB #1422
Input L17 DDB #048
CB2 Healthy DDB #437
Input L18 DDB #049
IM64 Ch1 Output1 DDB #112
IM64 Ch2 Output1 DDB #120
Input L19 DDB #050
CB1 Ext Trip A DDB #535
Input L20 DDB #051
CB1 Ext Trip B DDB #536
Input L21 DDB #052
CB1 Ext Trip C DDB #537
Input L22 DDB #053
CB2 Ext Trip A DDB #539
Input L23 DDB #054
CB2 Ext Trip B DDB #540
Input L24 DDB #055
CB2 Ext Trip C DDB #541
Opto L5 can be found on other pages
Page 1

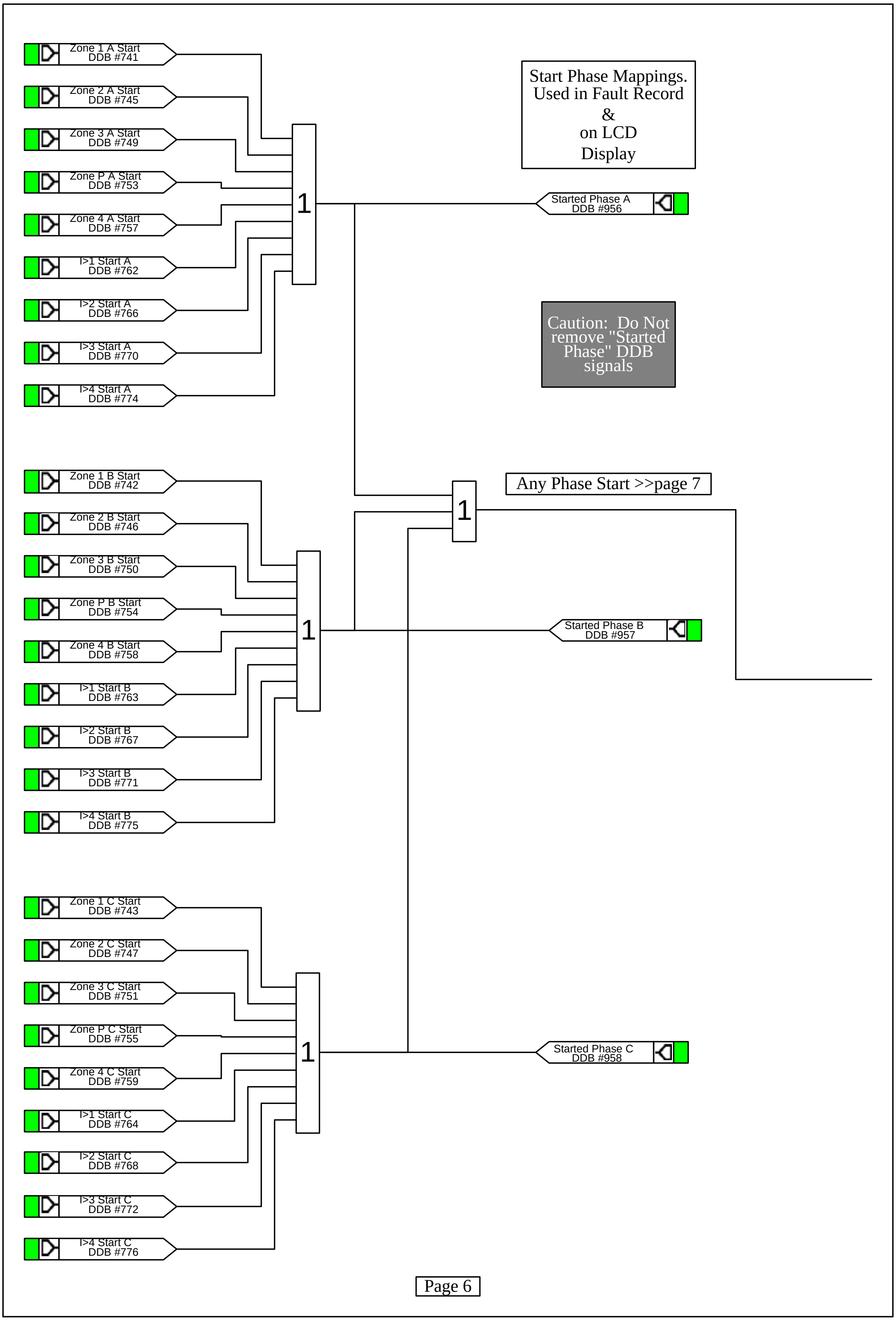
Output Contacts

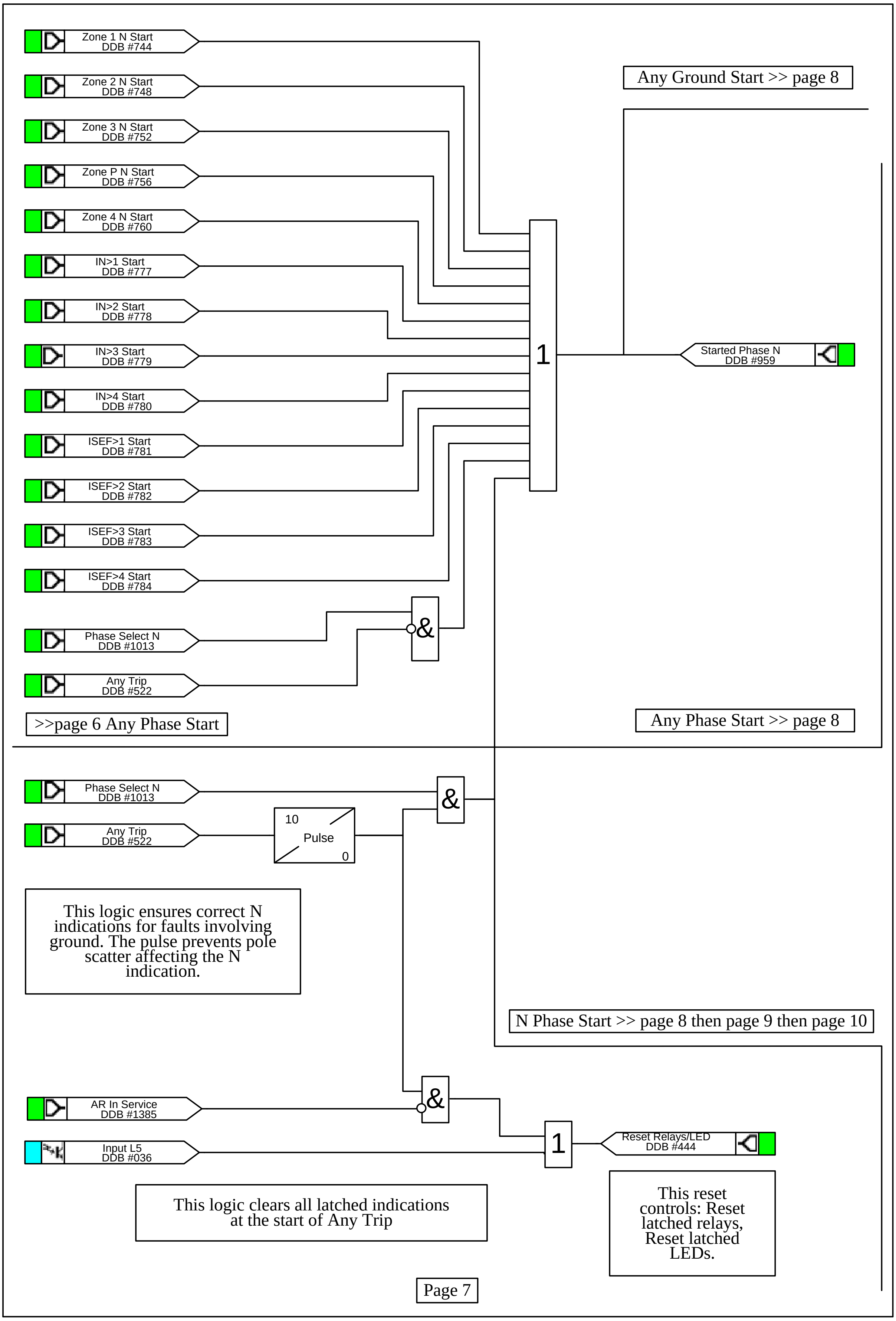

Zone 1 Trip DDB #608
0 Straight 0
Output R1 DDB #000
Any Trip DDB #522
100 Dwell 0
Output R3 DDB #002
IM64 Ch1 Input 1 DDB #096
IM64 Ch2 Input 1 DDB #104
1
0 Straight 0
Output R5 DDB #004
CB1 Fail1 Trip DDB #834
100 Dwell 0
Output R6 DDB #005
Control CloseCB1 DDB #839
0 Straight 0
Output R7 DDB #006
Control TripCB1 DDB #838
0 Straight 0
Output R8 DDB #007
CB1 Trip OutputA DDB #523
100 Dwell 0
Output R9 DDB #008
100 Dwell 0
Output R17 DDB #016
Trip Outputs are generated by the internal single/three phase trip conversion logic.
CB1 Trip OutputB DDB #524
100 Dwell 0
Output R10 DDB #009
100 Dwell 0
Output R18 DDB #017
CB1 Trip OutputC DDB #525
100 Dwell 0
Output R11 DDB #010
100 Dwell 0
Output R19 DDB #018
Page 2


SG-opto Invalid DDB #288
Prot'n Disabled DDB #289
Static Test Mode DDB #290
Test Loopback DDB #291
Test IM64 DDB #292
VT Fail Alarm DDB #293
CT1 Fail Alarm DDB #294
CT2 Fail Alarm DDB #295
Power Swing DDB #297
CB1 Fail Alarm DDB #298
CB1 Monitor Alm DDB #299
CB1 Mon LO Alarm DDB #300
CB1 Status Alm DDB #301
NoCS CB1ManClose DDB #305
CB1 AR Lockout DDB #306
AR CB1 Unhealthy DDB #307
AR CB1 No C/S DDB #308
CB1 Trip Fail DDB #302
CB1 Close Fail DDB #303
ManCB1 Unhealthy DDB #304
Signalling Fail DDB #311
IM64 SchemeFail DDB #314
IEEE C37.94 Fail DDB #315
Aid 1 Chan Fail DDB #317
Aid 2 Chan Fail DDB #318
F out of Range DDB #319
1
General Alarm
part of General Alarm >> page 4
Page 3


CB2 Fail Alarm
DDB #320
CB2 Status Alm
DDB #323
CB2 Monitor Alm
DDB #321
CB2 Mon LO Alarm
DDB #322
NoCS CB2ManClose
DDB #327
CB2 AR Lockout
DDB #328
AR CB2 No C/S
DDB #330
CB2 Trip Fail
DDB #324
CB2 Close Fail
DDB #325
ManCB2 Unhealthy
DDB #326
InValid Mesg Fmt
DDB #333
Main Prot. Fail
DDB #334
Comms Changed
DDB #337
Battery Fail
DDB #352
Field Volts Fail
DDB #353
Max Prop. Alarm
DDB #338
1
500
Dwell
0
Output R4
DDB #003
General Alarm
>>page 3 part of General Alarm
Page 4


ARIP
DDB #1542
0
Straight
0
Output R12
DDB #011
Control CloseCB2
DDB #841
0
Straight
0
Output R13
DDB #012
Control TripCB2
DDB #840
0
Straight
0
Output R14
DDB #013
CB2 Fail1 Trip
DDB #836
100
Dwell
0
Output R15
DDB #014
Aided 1 Send
DDB #498
0
Straight
0
Output R16
DDB #015
CB1 Trip 3ph
DDB #526
100
Dwell
0
Output R20
DDB #019
CB2 Trip OutputA
DDB #1601
100
Dwell
0
Output R21
DDB #020
Trip Outputs are generated by the internal single/three phase trip conversion logic.
CB2 Trip OutputB
DDB #1602
100
Dwell
0
Output R22
DDB #021
CB2 Trip OutputC
DDB #1603
100
Dwell
0
Output R23
DDB #022
CB2 Trip 3ph
DDB #1600
100
Dwell
0
Output R24
DDB #023
Page 5

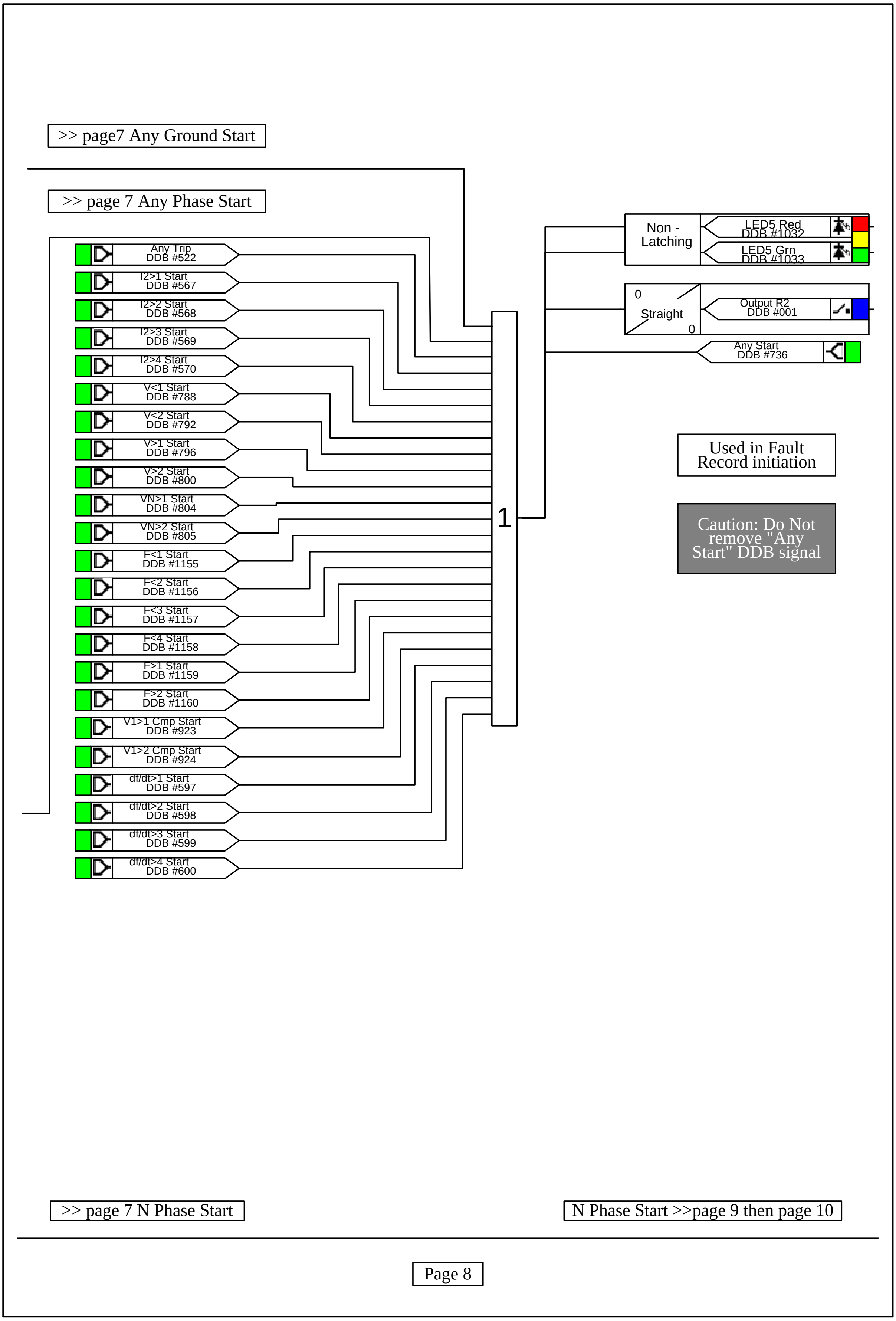

Zone 1 A Start DDB #741
Zone 2 A Start DDB #745
Zone 3 A Start DDB #749
Zone P A Start DDB #753
Zone 4 A Start DDB #757
I>1 Start A DDB #762
I>2 Start A DDB #766
I>3 Start A DDB #770
I>4 Start A DDB #774
1
Start Phase Mappings. Used in Fault Record & on LCD Display
Started Phase A DDB #956
Caution: Do Not remove "Started Phase" DDB signals
Any Phase Start >>page 7
1
Zone 1 B Start DDB #742
Zone 2 B Start DDB #746
Zone 3 B Start DDB #750
Zone P B Start DDB #754
Zone 4 B Start DDB #758
I>1 Start B DDB #763
I>2 Start B DDB #767
I>3 Start B DDB #771
I>4 Start B DDB #775
1
Started Phase B DDB #957
Zone 1 C Start DDB #743
Zone 2 C Start DDB #747
Zone 3 C Start DDB #751
Zone P C Start DDB #755
Zone 4 C Start DDB #759
I>1 Start C DDB #764
I>2 Start C DDB #768
I>3 Start C DDB #772
I>4 Start C DDB #776
1
Started Phase C DDB #958
Page 6

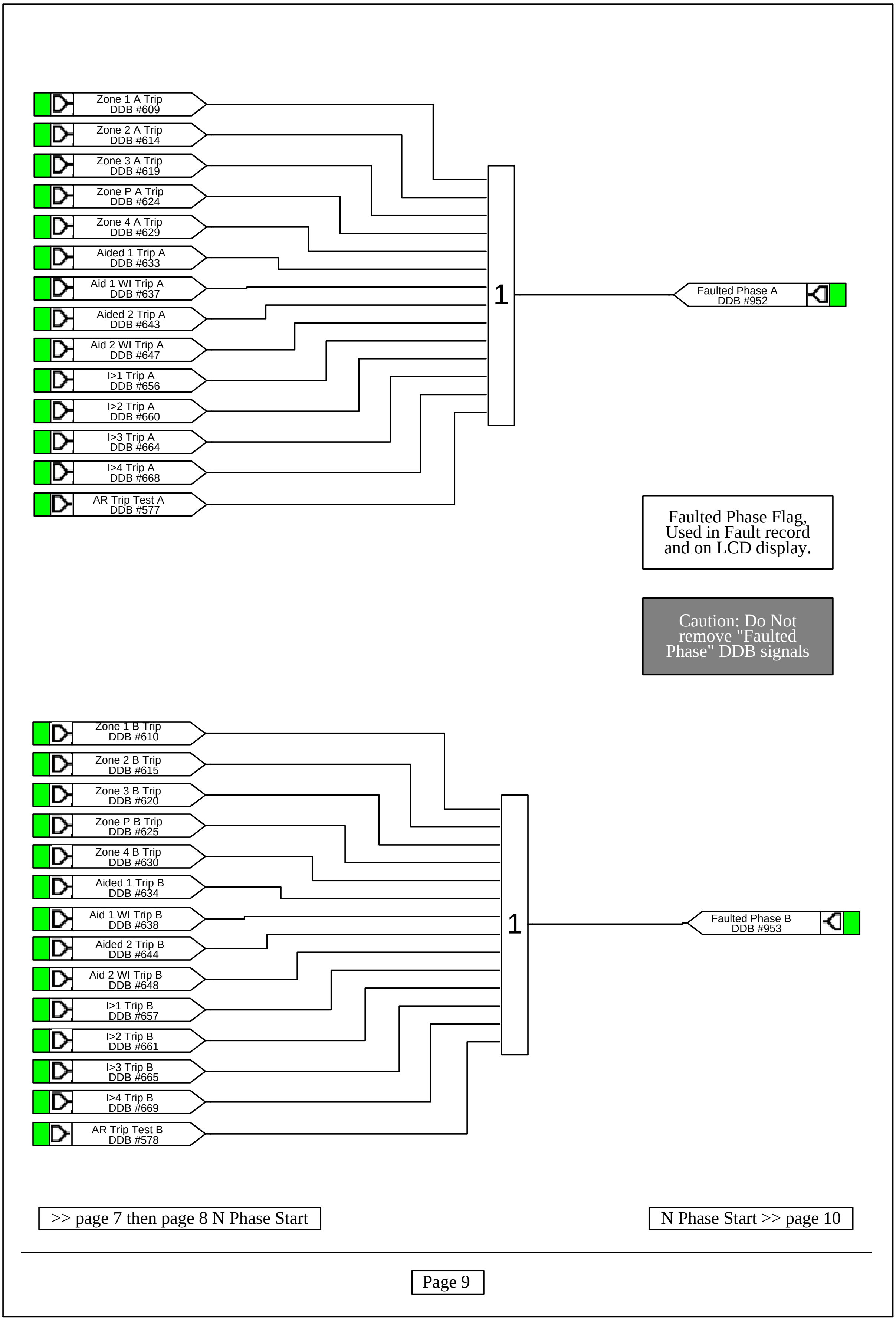

Zone 1 N Start
DDB #744
Zone 2 N Start
DDB #748
Zone 3 N Start
DDB #752
Zone P N Start
DDB #756
Zone 4 N Start
DDB #760
IN>1 Start
DDB #777
IN>2 Start
DDB #778
IN>3 Start
DDB #779
IN>4 Start
DDB #780
ISEF>1 Start
DDB #781
ISEF>2 Start
DDB #782
ISEF>3 Start
DDB #783
ISEF>4 Start
DDB #784
Phase Select N
DDB #1013
Any Trip
DDB #522
&
1
Any Ground Start >> page 8
Started Phase N
DDB #959
>>page 6 Any Phase Start
Any Phase Start >> page 8
Phase Select N
DDB #1013
Any Trip
DDB #522
10
Pulse
0
&
N Phase Start >> page 8 then page 9 then page 10
AR In Service
DDB #1385
Input L5
DDB #036
&
1
Reset Relays/LED
DDB #444
Page 7

This logic ensures correct N indications for faults involving ground. The pulse prevents pole scatter affecting the N indication.

This logic clears all latched indications at the start of Any Trip

This reset controls: Reset latched relays, Reset latched LEDs.


>> page7 Any Ground Start
>> page 7 Any Phase Start
Any Trip DDB #522
I2>1 Start DDB #567
I2>2 Start DDB #568
I2>3 Start DDB #569
I2>4 Start DDB #570
V<1 Start DDB #788
V<2 Start DDB #792
V>1 Start DDB #796
V>2 Start DDB #800
VN>1 Start DDB #804
VN>2 Start DDB #805
F<1 Start DDB #1155
F<2 Start DDB #1156
F<3 Start DDB #1157
F<4 Start DDB #1158
F>1 Start DDB #1159
F>2 Start DDB #1160
V1>1 Cmp Start DDB #923
V1>2 Cmp Start DDB #924
df/dt>1 Start DDB #597
df/dt>2 Start DDB #598
df/dt>3 Start DDB #599
df/dt>4 Start DDB #600
1
Non - Latching
LED5 Red DDB #1032
LED5 Grn DDB #1033
0
Straight
0
Output R2 DDB #001
Any Start DDB #736
Used in Fault Record initiation
Caution: Do Not remove "Any Start" DDB signal
>> page 7 N Phase Start
N Phase Start >>page 9 then page 10
Page 8


Zone 1 A Trip DDB #609
Zone 2 A Trip DDB #614
Zone 3 A Trip DDB #619
Zone P A Trip DDB #624
Zone 4 A Trip DDB #629
Aided 1 Trip A DDB #633
Aid 1 WI Trip A DDB #637
Aided 2 Trip A DDB #643
Aid 2 WI Trip A DDB #647
I>1 Trip A DDB #656
I>2 Trip A DDB #660
I>3 Trip A DDB #664
I>4 Trip A DDB #668
AR Trip Test A DDB #577
1
Faulted Phase A DDB #952
Zone 1 B Trip DDB #610
Zone 2 B Trip DDB #615
Zone 3 B Trip DDB #620
Zone P B Trip DDB #625
Zone 4 B Trip DDB #630
Aided 1 Trip B DDB #634
Aid 1 WI Trip B DDB #638
Aided 2 Trip B DDB #644
Aid 2 WI Trip B DDB #648
I>1 Trip B DDB #657
I>2 Trip B DDB #661
I>3 Trip B DDB #665
I>4 Trip B DDB #669
AR Trip Test B DDB #578
1
Faulted Phase B DDB #953

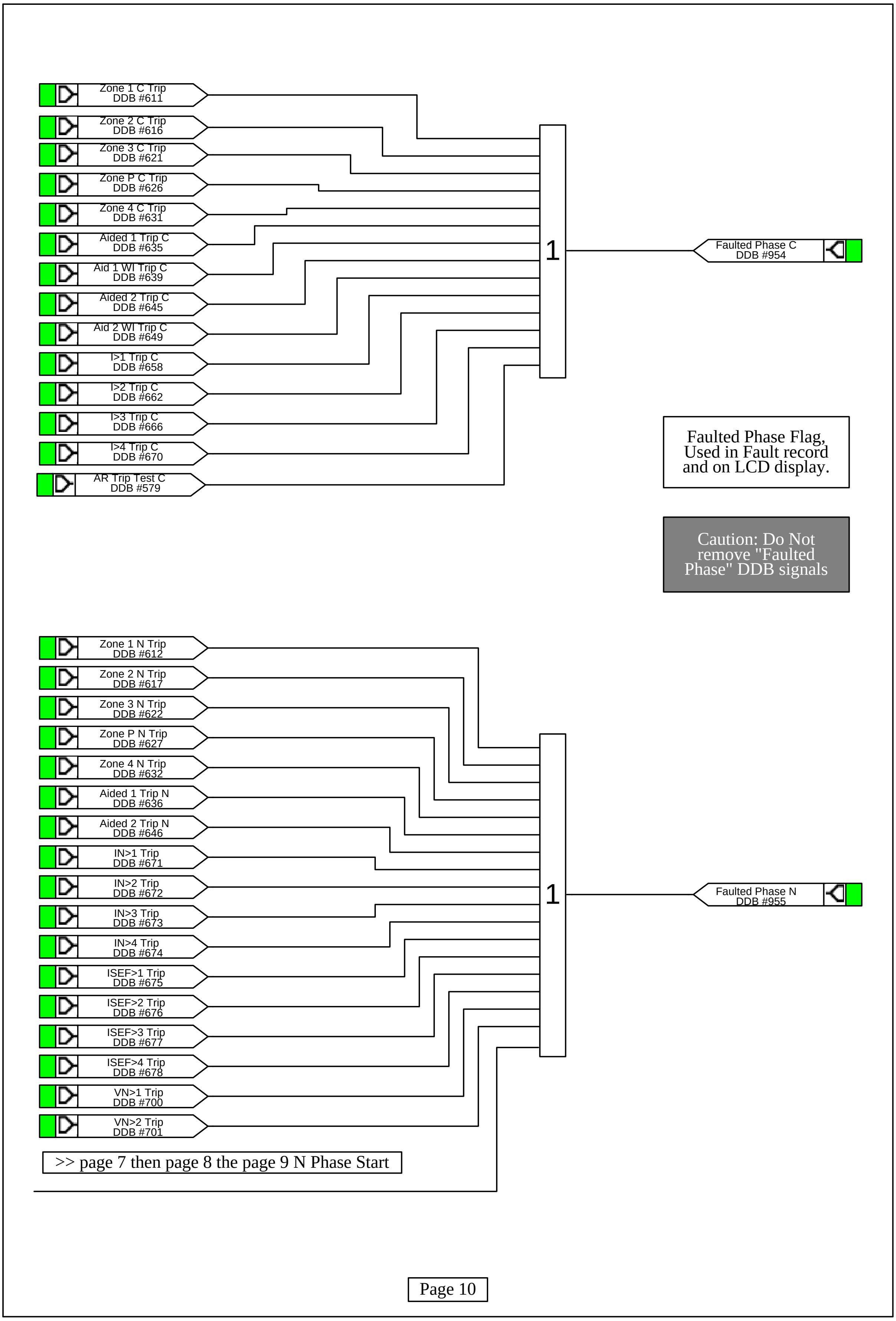
Faulted Phase Flag, Used in Fault record and on LCD display.

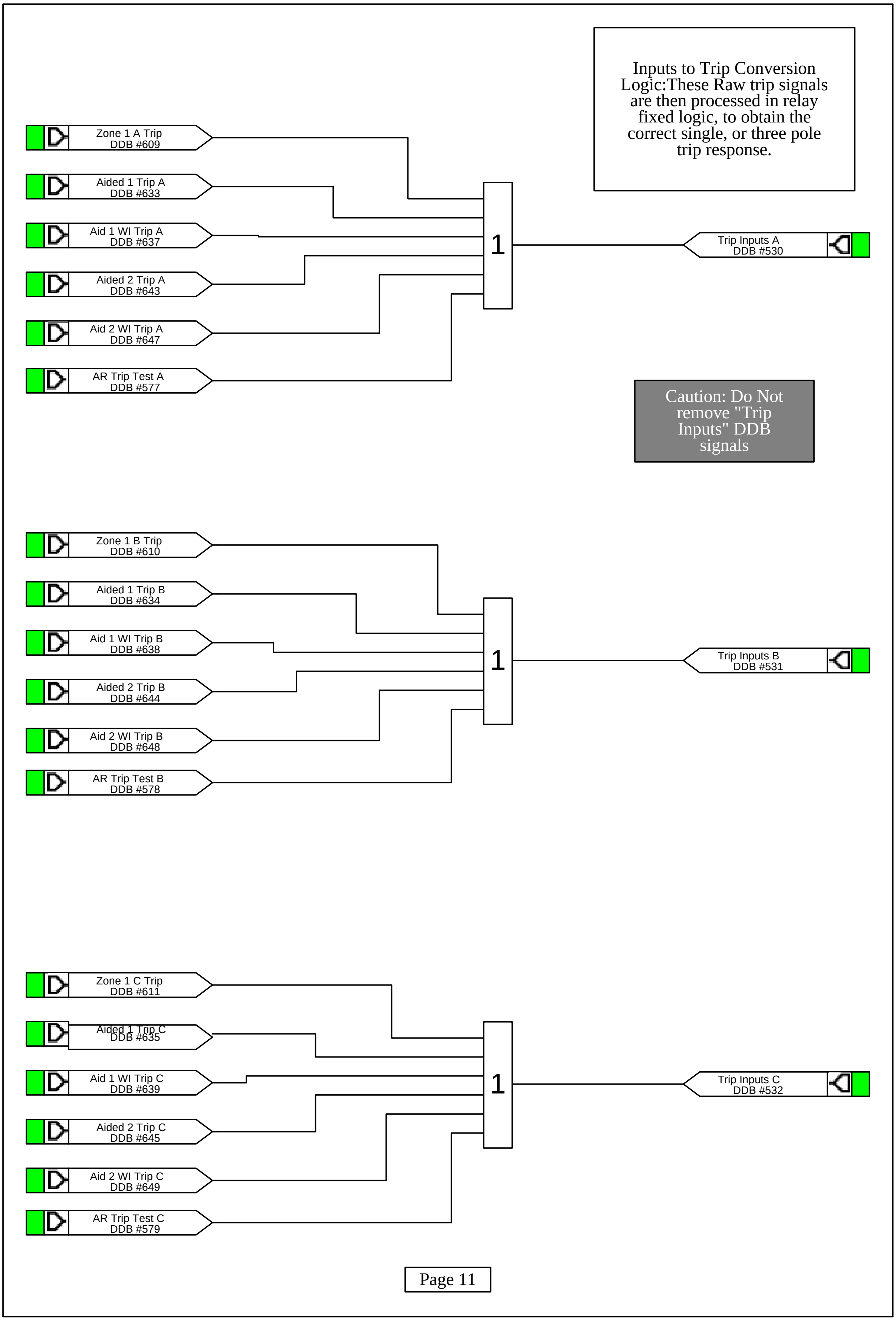
Caution: Do Not remove "Faulted Phase" DDB signals

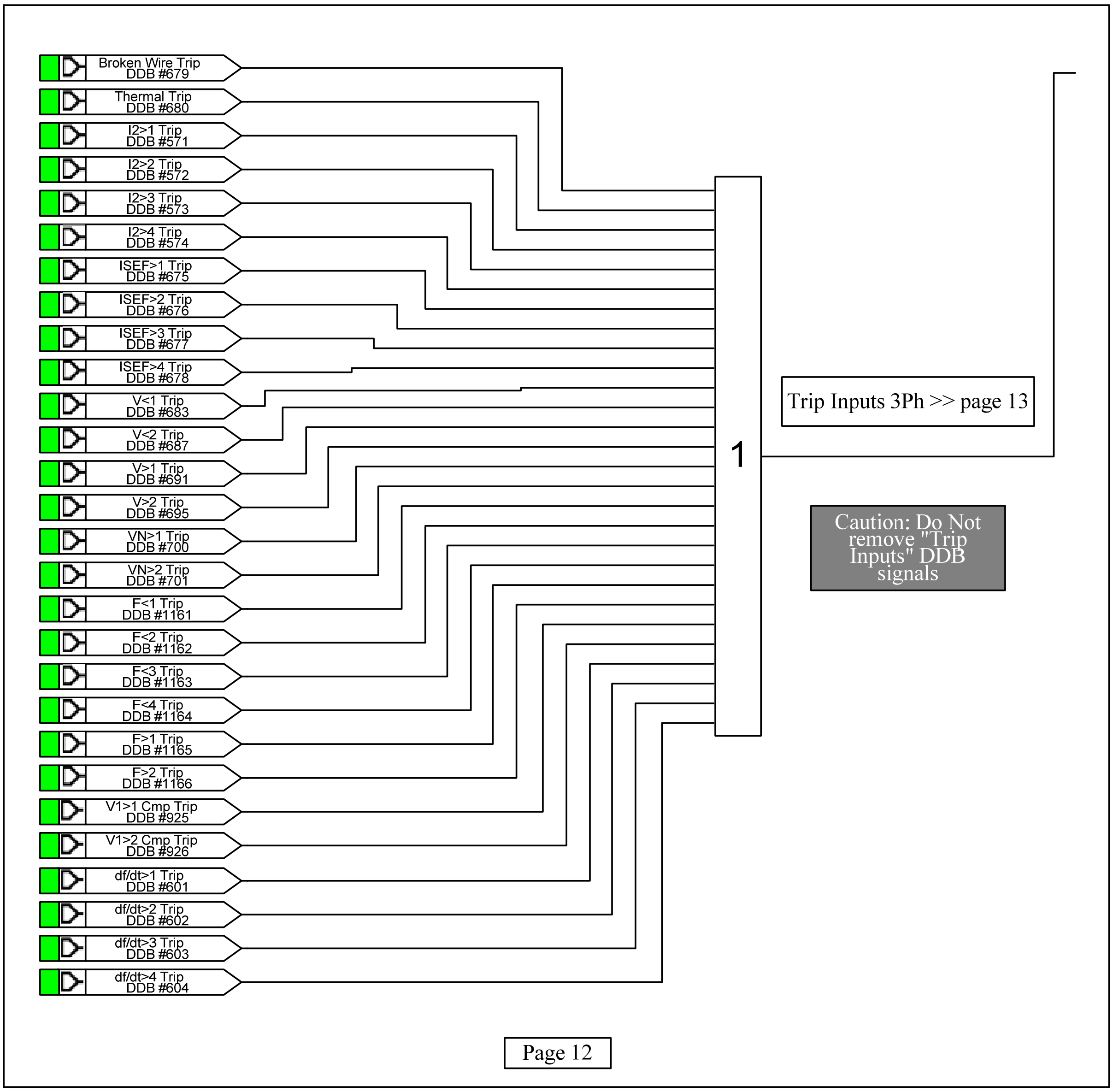
>> page 7 then page 8 N Phase Start

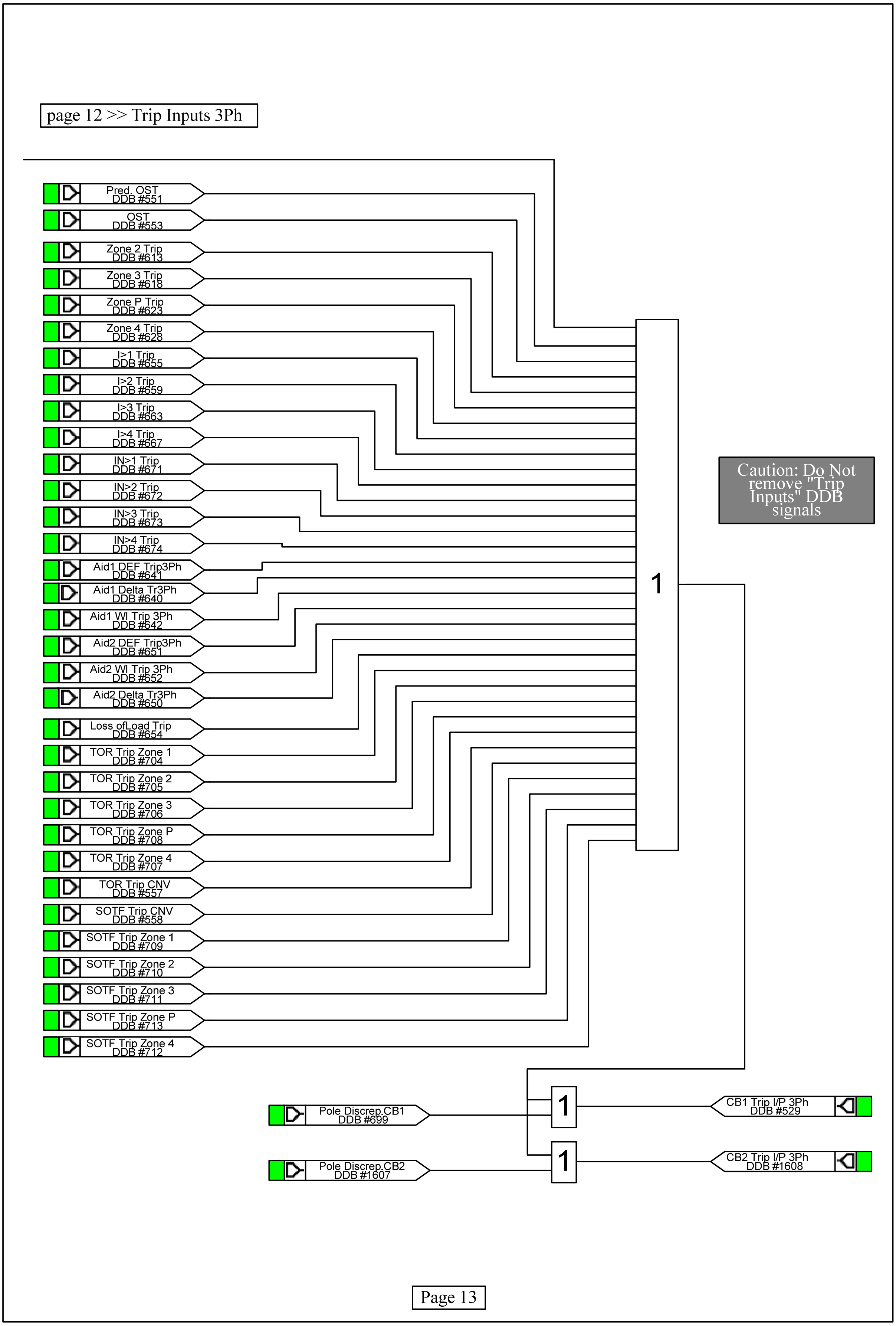
N Phase Start >> page 10

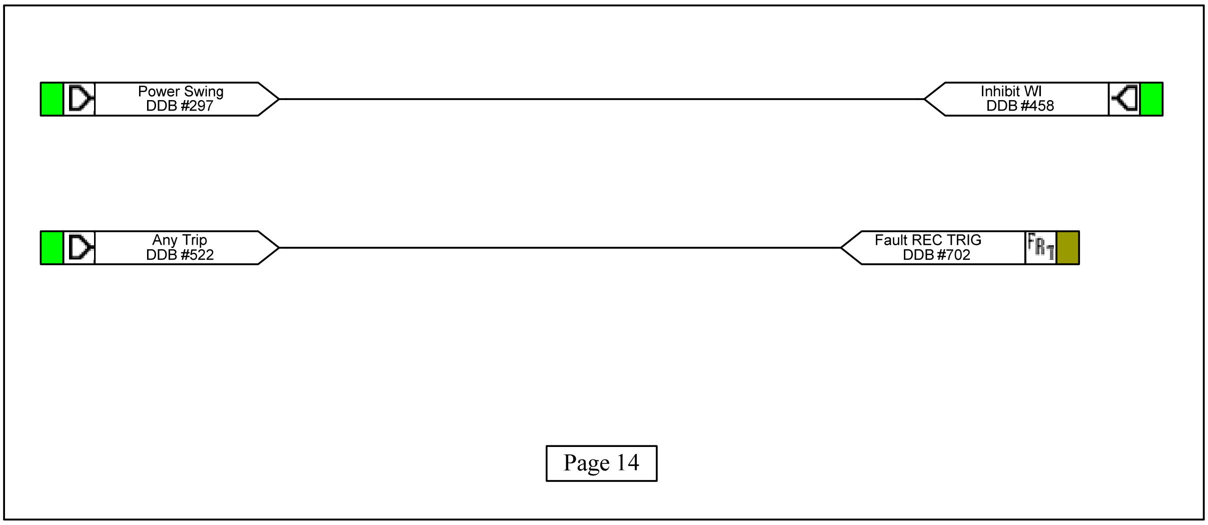
Page 9


Zone 1 C Trip DDB #611
Zone 2 C Trip DDB #616
Zone 3 C Trip DDB #621
Zone P C Trip DDB #626
Zone 4 C Trip DDB #631
Aided 1 Trip C DDB #635
Aid 1 WI Trip C DDB #639
Aided 2 Trip C DDB #645
Aid 2 WI Trip C DDB #649
I>1 Trip C DDB #658
I>2 Trip C DDB #662
I>3 Trip C DDB #666
I>4 Trip C DDB #670
AR Trip Test C DDB #579
1
Faulted Phase C DDB #954
Faulted Phase Flag, Used in Fault record and on LCD display.
Caution: Do Not remove "Faulted Phase" DDB signals
Zone 1 N Trip DDB #612
Zone 2 N Trip DDB #617
Zone 3 N Trip DDB #622
Zone P N Trip DDB #627
Zone 4 N Trip DDB #632
Aided 1 Trip N DDB #636
Aided 2 Trip N DDB #646
IN>1 Trip DDB #671
IN>2 Trip DDB #672
IN>3 Trip DDB #673
IN>4 Trip DDB #674
ISEF>1 Trip DDB #675
ISEF>2 Trip DDB #676
ISEF>3 Trip DDB #677
ISEF>4 Trip DDB #678
VN>1 Trip DDB #700
VN>2 Trip DDB #701
1
Faulted Phase N DDB #955
>> page 7 then page 8 the page 9 N Phase Start
Page 10

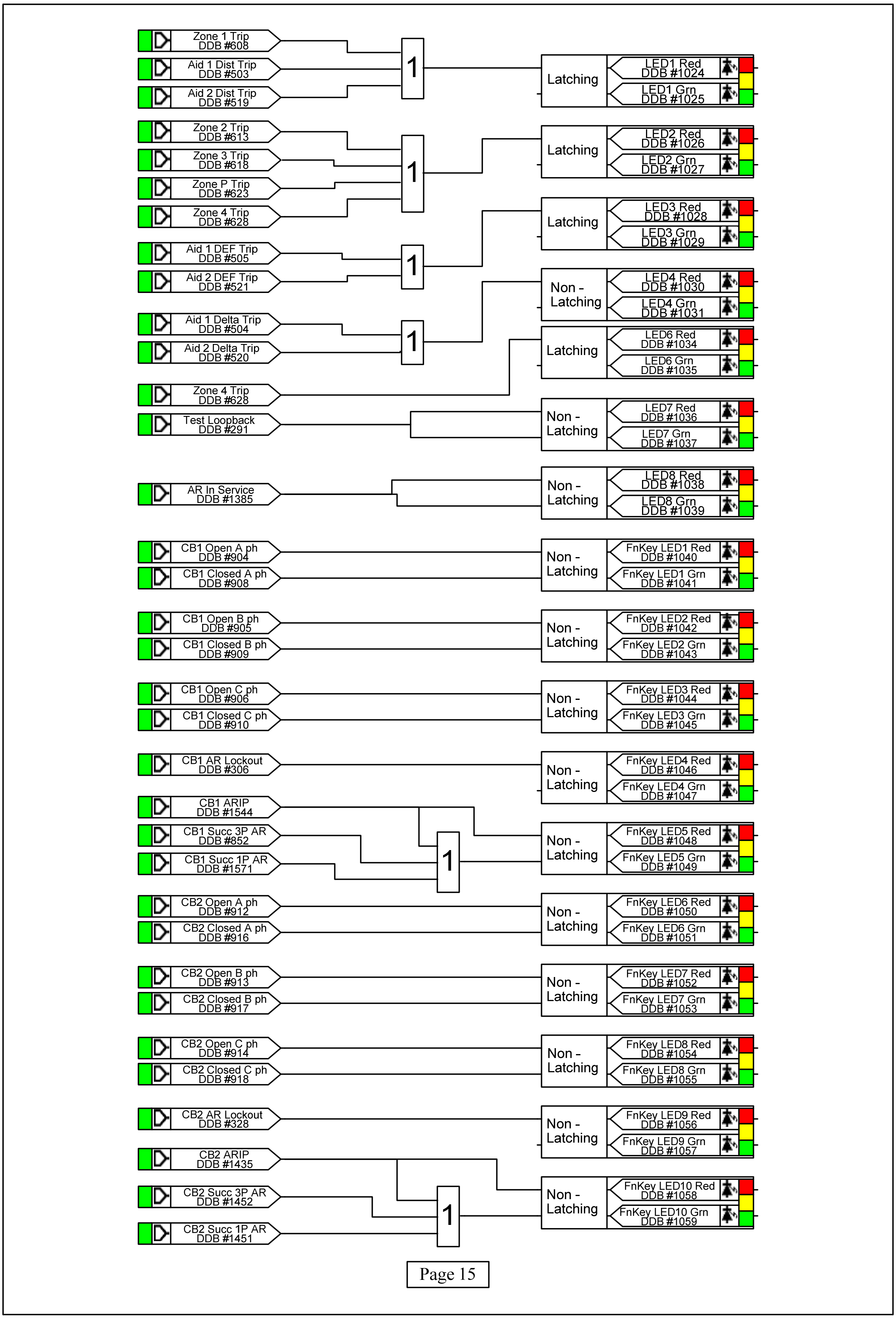

Inputs to Trip Conversion Logic:These Raw trip signals are then processed in relay fixed logic, to obtain the correct single, or three pole trip response.
Zone 1 A Trip DDB #609
Aided 1 Trip A DDB #633
Aid 1 WI Trip A DDB #637
Aided 2 Trip A DDB #643
Aid 2 WI Trip A DDB #647
AR Trip Test A DDB #577
1
Trip Inputs A DDB #530
Caution: Do Not remove "Trip Inputs" DDB signals
Zone 1 B Trip DDB #610
Aided 1 Trip B DDB #634
Aid 1 WI Trip B DDB #638
Aided 2 Trip B DDB #644
Aid 2 WI Trip B DDB #648
AR Trip Test B DDB #578
1
Trip Inputs B DDB #531
Zone 1 C Trip DDB #611
Aided 1 Trip C DDB #635
Aid 1 WI Trip C DDB #639
Aided 2 Trip C DDB #645
Aid 2 WI Trip C DDB #649
AR Trip Test C DDB #579
1
Trip Inputs C DDB #532
Page 11


Broken Wire Trip DDB #679
Thermal Trip DDB #680
I2>1 Trip DDB #571
I2>2 Trip DDB #572
I2>3 Trip DDB #573
I2>4 Trip DDB #574
ISEF>1 Trip DDB #675
ISEF>2 Trip DDB #676
ISEF>3 Trip DDB #677
ISEF>4 Trip DDB #678
V<1 Trip DDB #683
V<2 Trip DDB #687
V>1 Trip DDB #691
V>2 Trip DDB #695
VN>1 Trip DDB #700
VN>2 Trip DDB #701
F<1 Trip DDB #1161
F<2 Trip DDB #1162
F<3 Trip DDB #1163
F<4 Trip DDB #1164
F>1 Trip DDB #1165
F>2 Trip DDB #1166
V1>1 Cmp Trip DDB #925
V1>2 Cmp Trip DDB #926
df/dt>1 Trip DDB #601
df/dt>2 Trip DDB #602
df/dt>3 Trip DDB #603
df/dt>4 Trip DDB #604
1
Trip Inputs 3Ph >> page 13
Caution: Do Not remove "Trip Inputs" DDB signals
Page 12


page 12 >> Trip Inputs 3Ph
Pred. OST DDB #551
OST DDB #553
Zone 2 Trip DDB #613
Zone 3 Trip DDB #618
Zone P Trip DDB #623
Zone 4 Trip DDB #628
I>1 Trip DDB #655
I>2 Trip DDB #659
I>3 Trip DDB #663
I>4 Trip DDB #667
IN>1 Trip DDB #671
IN>2 Trip DDB #672
IN>3 Trip DDB #673
IN>4 Trip DDB #674
Aid1 DEF Trip3Ph DDB #641
Aid1 Delta Tr3Ph DDB #640
Aid1 WI Trip 3Ph DDB #642
Aid2 DEF Trip3Ph DDB #651
Aid2 WI Trip 3Ph DDB #652
Aid2 Delta Tr3Ph DDB #650
Loss ofLoad Trip DDB #654
TOR Trip Zone 1 DDB #704
TOR Trip Zone 2 DDB #705
TOR Trip Zone 3 DDB #706
TOR Trip Zone P DDB #708
TOR Trip Zone 4 DDB #707
TOR Trip CNV DDB #557
SOTF Trip CNV DDB #558
SOTF Trip Zone 1 DDB #709
SOTF Trip Zone 2 DDB #710
SOTF Trip Zone 3 DDB #711
SOTF Trip Zone P DDB #713
SOTF Trip Zone 4 DDB #712
1
Caution: Do Not remove "Trip Inputs" DDB signals
Pole Discrep.CB1 DDB #699
Pole Discrep.CB2 DDB #1607
1
1
CB1 Trip I/P 3Ph DDB #529
CB2 Trip I/P 3Ph DDB #1608
Page 13

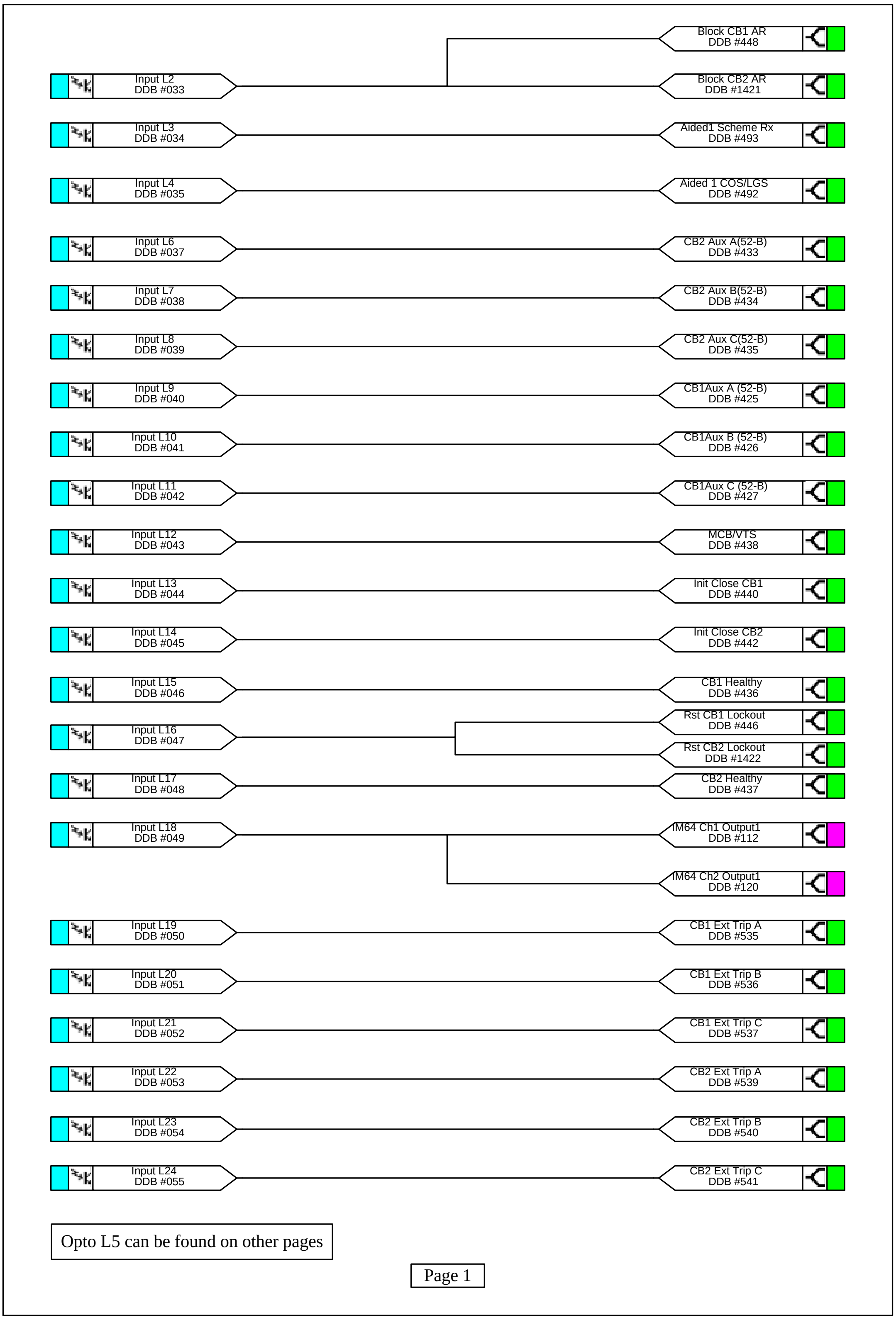

Power Swing
DDB #297
Inhibit WI
DDB #458
Any Trip
DDB #522
Fault REC TRIG
DDB #702
FRT
Page 14

LEDs

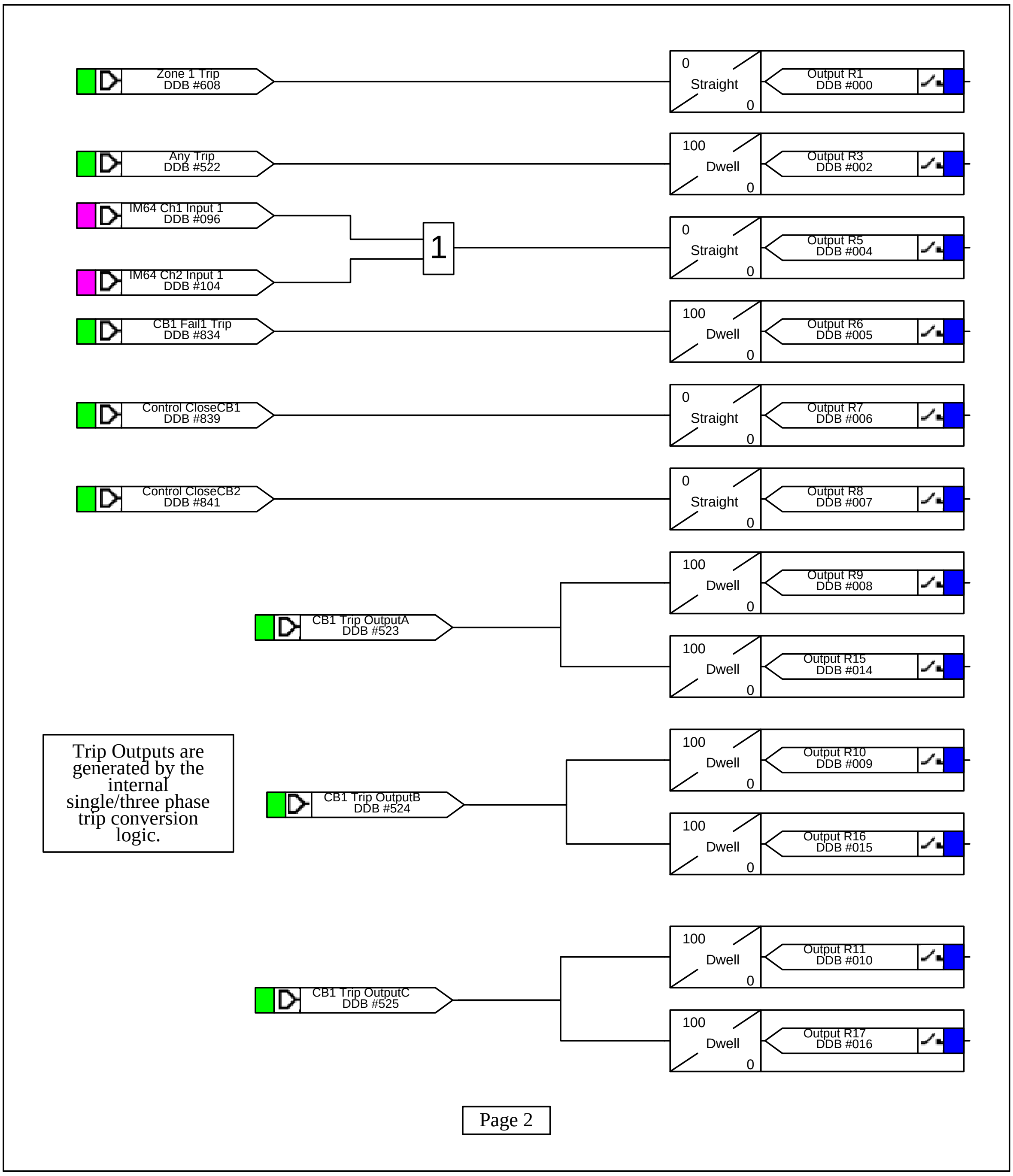

Zone 1 Trip DDB #608
Aid 1 Dist Trip DDB #503
Aid 2 Dist Trip DDB #519
1
Latching
LED1 Red DDB #1024
LED1 Grn DDB #1025
Zone 2 Trip DDB #613
Zone 3 Trip DDB #618
Zone P Trip DDB #623
Zone 4 Trip DDB #628
1
Latching
LED2 Red DDB #1026
LED2 Grn DDB #1027
Aid 1 DEF Trip DDB #505
Aid 2 DEF Trip DDB #521
1
Latching
LED3 Red DDB #1028
LED3 Grn DDB #1029
Non - Latching
LED4 Red DDB #1030
LED4 Grn DDB #1031
Aid 1 Delta Trip DDB #504
Aid 2 Delta Trip DDB #520
1
Latching
LED6 Red DDB #1034
LED6 Grn DDB #1035
Zone 4 Trip DDB #628
Test Loopback DDB #291
Non - Latching
LED7 Red DDB #1036
LED7 Grn DDB #1037
AR In Service DDB #1385
Non - Latching
LED8 Red DDB #1038
LED8 Grn DDB #1039
CB1 Open A ph DDB #904
CB1 Closed A ph DDB #908
Non - Latching
FnKey LED1 Red DDB #1040
FnKey LED1 Grn DDB #1041
CB1 Open B ph DDB #905
CB1 Closed B ph DDB #909
Non - Latching
FnKey LED2 Red DDB #1042
FnKey LED2 Grn DDB #1043
CB1 Open C ph DDB #906
CB1 Closed C ph DDB #910
Non - Latching
FnKey LED3 Red DDB #1044
FnKey LED3 Grn DDB #1045
CB1 AR Lockout DDB #306
Non - Latching
FnKey LED4 Red DDB #1046
FnKey LED4 Grn DDB #1047
CB1 ARIP DDB #1544
CB1 Succ 3P AR DDB #852
CB1 Succ 1P AR DDB #1571
1
Non - Latching
FnKey LED5 Red DDB #1048
FnKey LED5 Grn DDB #1049
CB2 Open A ph DDB #912
CB2 Closed A ph DDB #916
Non - Latching
FnKey LED6 Red DDB #1050
FnKey LED6 Grn DDB #1051
CB2 Open B ph DDB #913
CB2 Closed B ph DDB #917
Non - Latching
FnKey LED7 Red DDB #1052
FnKey LED7 Grn DDB #1053
CB2 Open C ph DDB #914
CB2 Closed C ph DDB #918
Non - Latching
FnKey LED8 Red DDB #1054
FnKey LED8 Grn DDB #1055
CB2 AR Lockout DDB #328
Non - Latching
FnKey LED9 Red DDB #1056
FnKey LED9 Grn DDB #1057
CB2 ARIP DDB #1435
CB2 Succ 3P AR DDB #1452
CB2 Succ 1P AR DDB #1451
1
Non - Latching
FnKey LED10 Red DDB #1058
FnKey LED10 Grn DDB #1059
Page 15

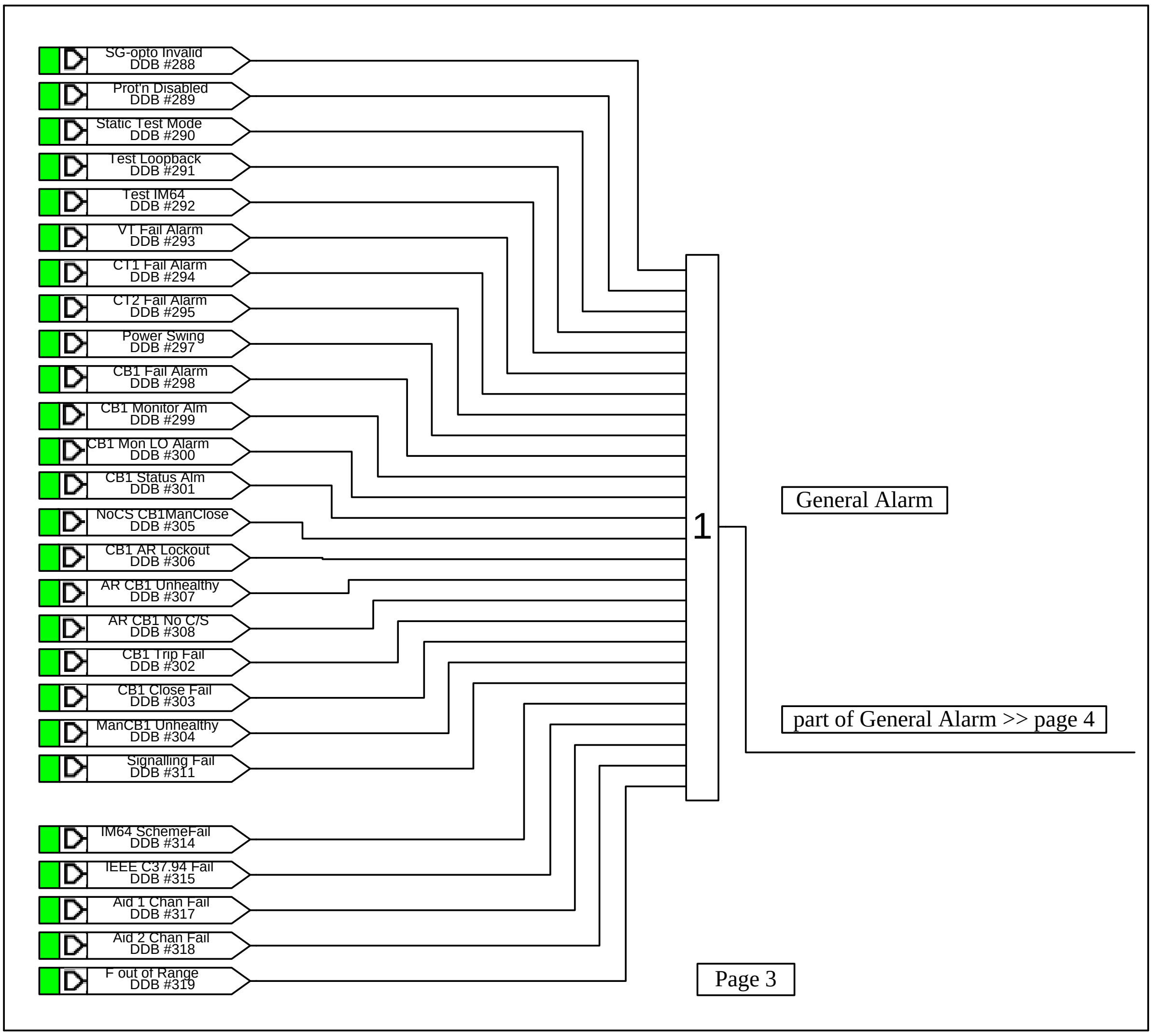
P446 WITH STANDARD CONTACTS PSL 8 STD + 12 HIGH BREAK RELAYS

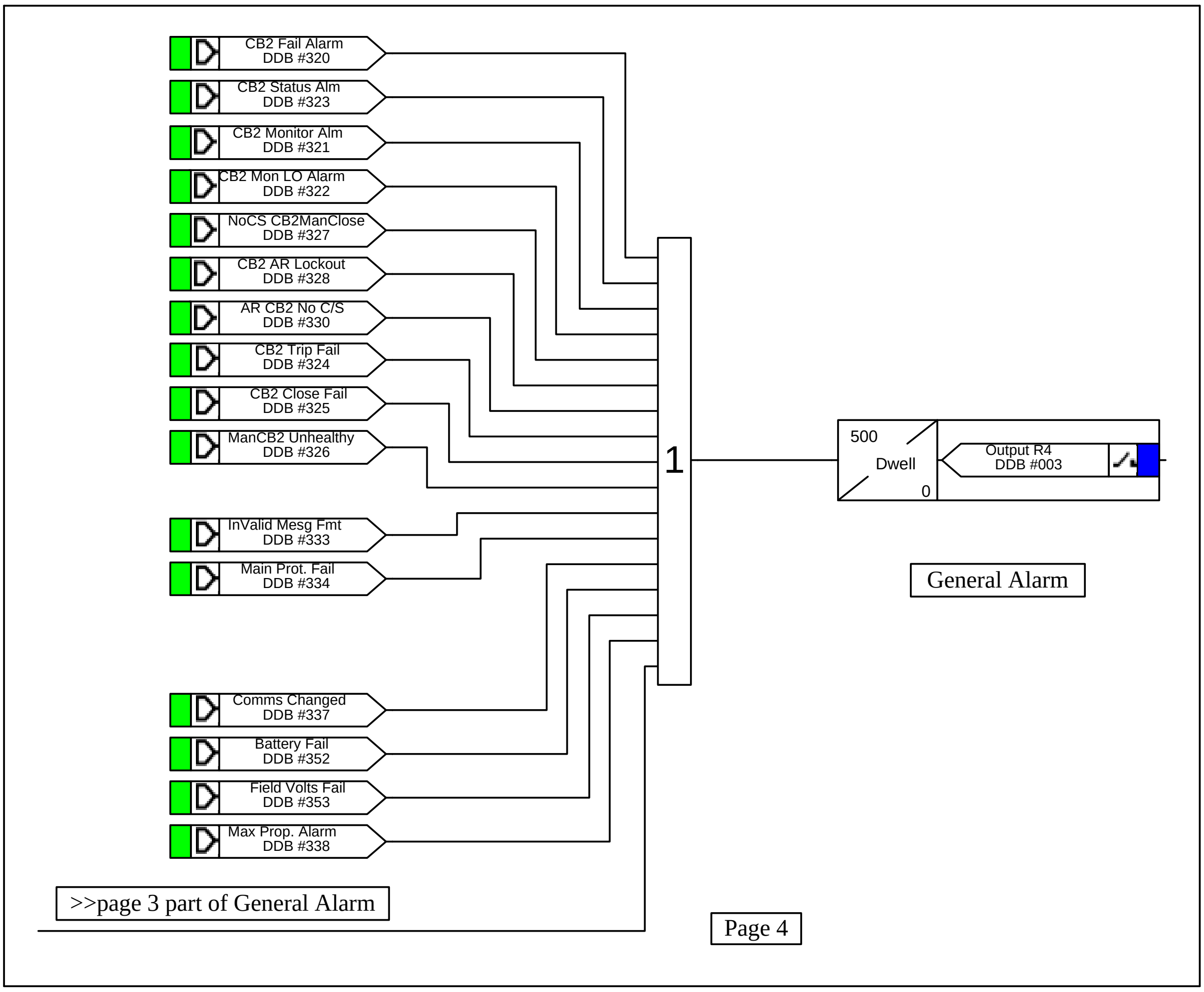
Opto Input Mappings

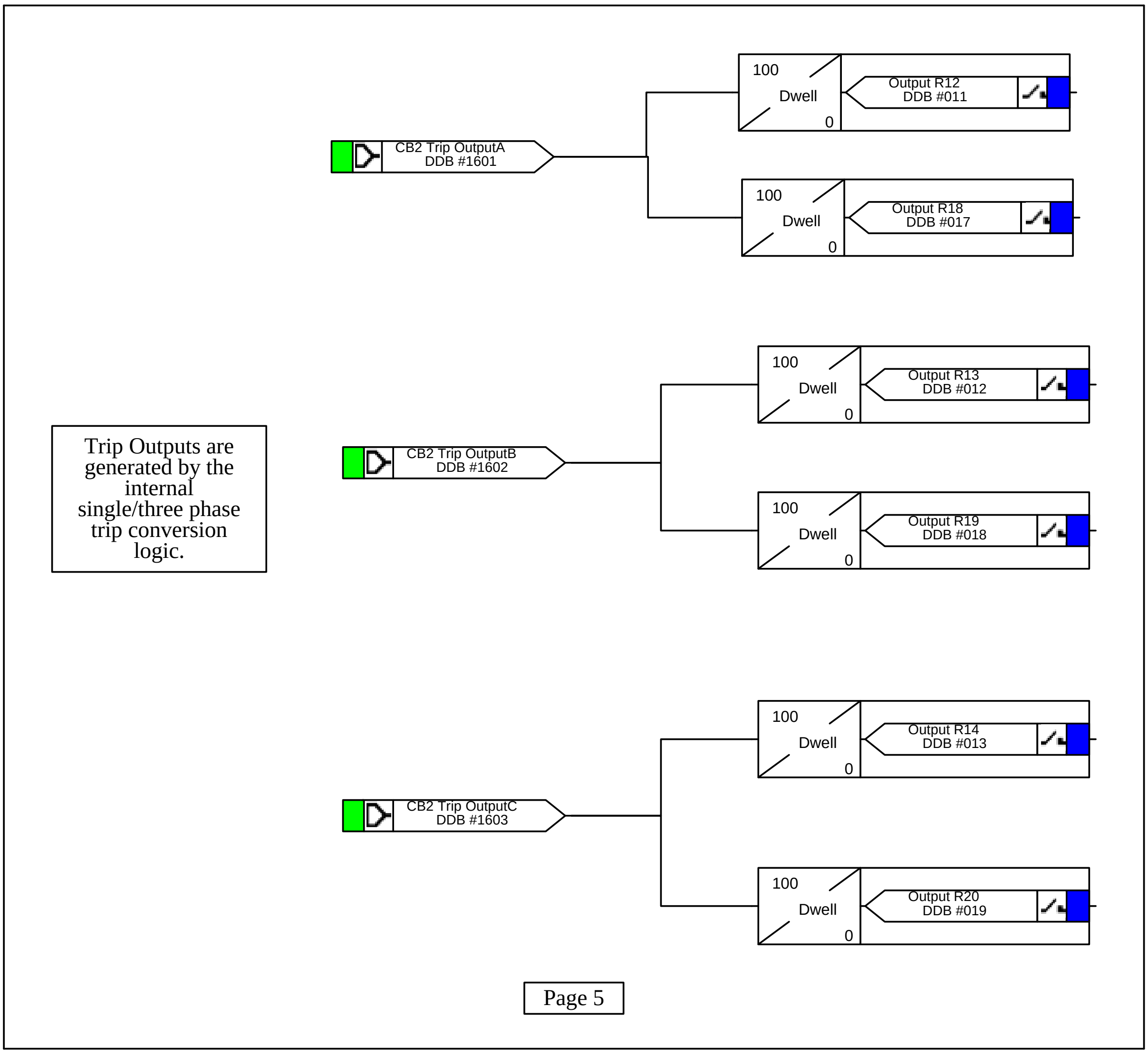

Block CB1 AR DDB #448
Input L2 DDB #033
Block CB2 AR DDB #1421
Input L3 DDB #034
Aided1 Scheme Rx DDB #493
Input L4 DDB #035
Aided 1 COS/LGS DDB #492
Input L6 DDB #037
CB2 Aux A(52-B) DDB #433
Input L7 DDB #038
CB2 Aux B(52-B) DDB #434
Input L8 DDB #039
CB2 Aux C(52-B) DDB #435
Input L9 DDB #040
CB1Aux A (52-B) DDB #425
Input L10 DDB #041
CB1Aux B (52-B) DDB #426
Input L11 DDB #042
CB1Aux C (52-B) DDB #427
Input L12 DDB #043
MCB/VTS DDB #438
Input L13 DDB #044
Init Close CB1 DDB #440
Input L14 DDB #045
Init Close CB2 DDB #442
Input L15 DDB #046
CB1 Healthy DDB #436
Input L16 DDB #047
Rst CB1 Lockout DDB #446
Rst CB2 Lockout DDB #1422
Input L17 DDB #048
CB2 Healthy DDB #437
Input L18 DDB #049
IM64 Ch1 Output1 DDB #112
IM64 Ch2 Output1 DDB #120
Input L19 DDB #050
CB1 Ext Trip A DDB #535
Input L20 DDB #051
CB1 Ext Trip B DDB #536
Input L21 DDB #052
CB1 Ext Trip C DDB #537
Input L22 DDB #053
CB2 Ext Trip A DDB #539
Input L23 DDB #054
CB2 Ext Trip B DDB #540
Input L24 DDB #055
CB2 Ext Trip C DDB #541
Opto L5 can be found on other pages
Page 1

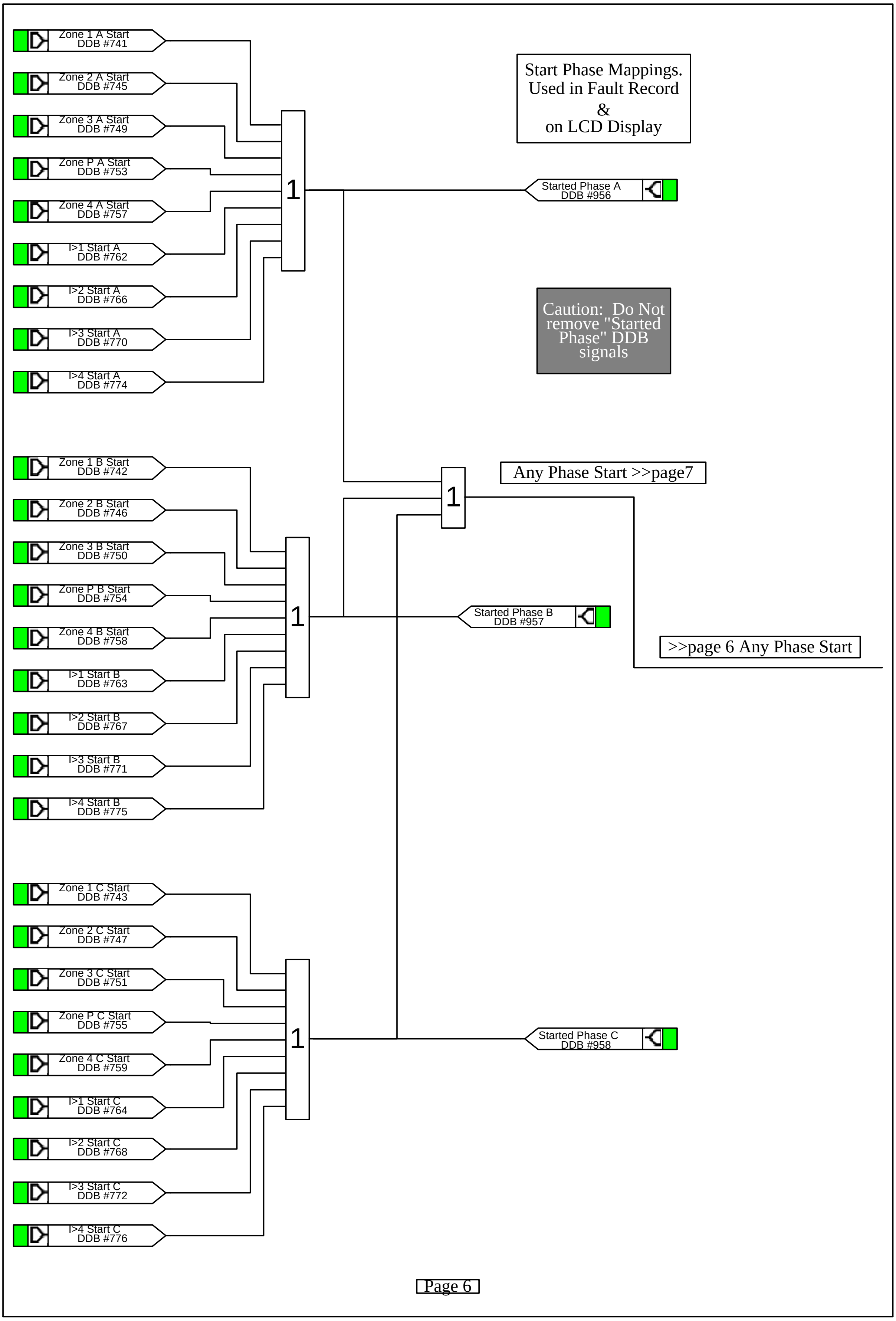
Output Contacts

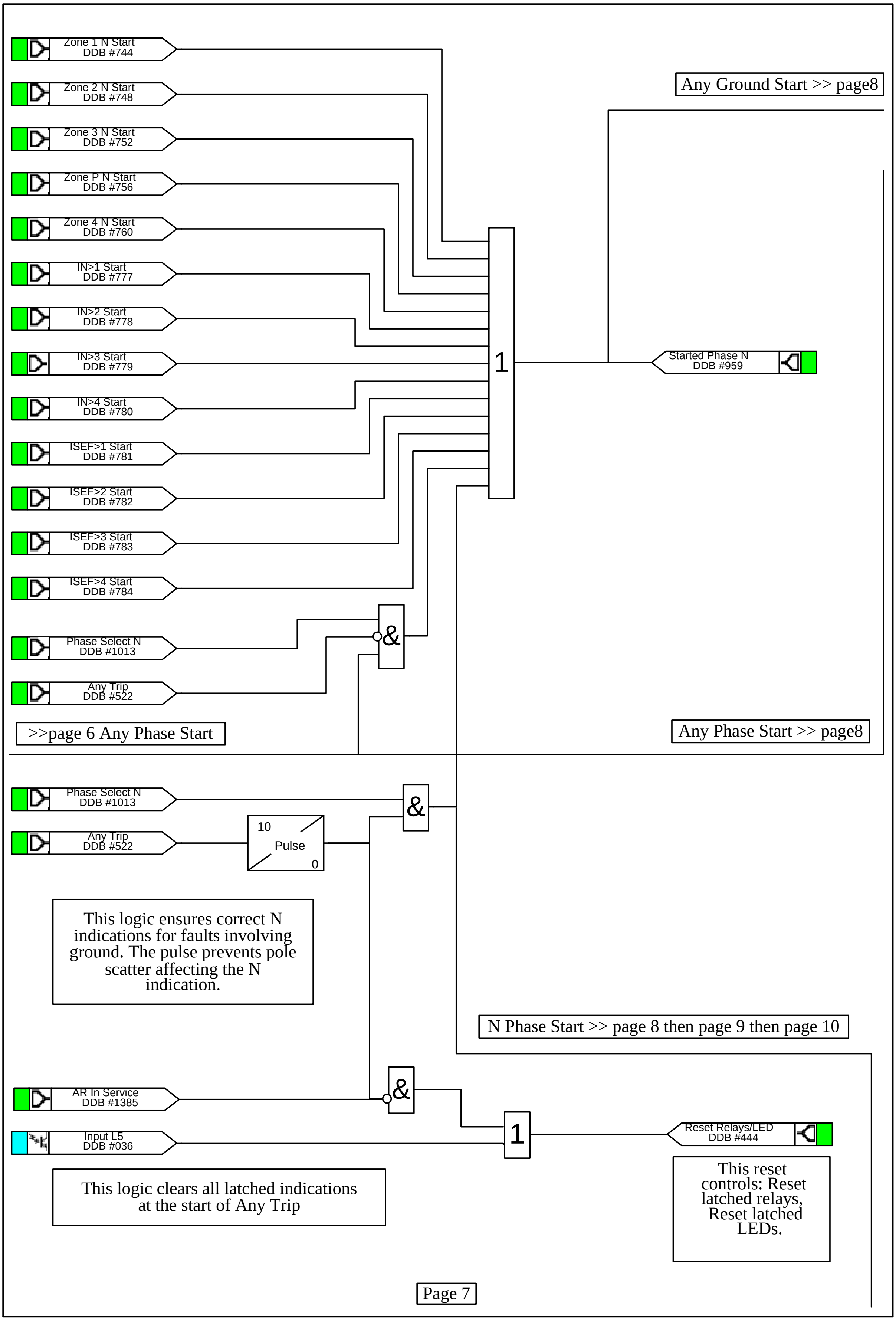

Zone 1 Trip
DDB #608
Any Trip
DDB #522
IM64 Ch1 Input 1
DDB #096
IM64 Ch2 Input 1
DDB #104
1
CB1 Fail1 Trip
DDB #834
Control CloseCB1
DDB #839
Control CloseCB2
DDB #841
CB1 Trip OutputA
DDB #523
CB1 Trip OutputB
DDB #524
CB1 Trip OutputC
DDB #525
Trip Outputs are generated by the internal single/three phase trip conversion logic.
0 Straight 0
Output R1
DDB #000
100 Dwell 0
Output R3
DDB #002
0 Straight 0
Output R5
DDB #004
100 Dwell 0
Output R6
DDB #005
0 Straight 0
Output R7
DDB #006
0 Straight 0
Output R8
DDB #007
100 Dwell 0
Output R9
DDB #008
100 Dwell 0
Output R15
DDB #014
100 Dwell 0
Output R10
DDB #009
100 Dwell 0
Output R16
DDB #015
100 Dwell 0
Output R11
DDB #010
100 Dwell 0
Output R17
DDB #016
Page 2


SG-opto Invalid
DDB #288
Prot'n Disabled
DDB #289
Static Test Mode
DDB #290
Test Loopback
DDB #291
Test IM64
DDB #292
VT Fail Alarm
DDB #293
CT1 Fail Alarm
DDB #294
CT2 Fail Alarm
DDB #295
Power Swing
DDB #297
CB1 Fail Alarm
DDB #298
CB1 Monitor Alm
DDB #299
CB1 Mon LO Alarm
DDB #300
CB1 Status Alm
DDB #301
NoCS CB1ManClose
DDB #305
CB1 AR Lockout
DDB #306
AR CB1 Unhealthy
DDB #307
AR CB1 No C/S
DDB #308
CB1 Trip Fail
DDB #302
CB1 Close Fail
DDB #303
ManCB1 Unhealthy
DDB #304
Signalling Fail
DDB #311
IM64 SchemeFail
DDB #314
IEEE C37.94 Fail
DDB #315
Aid 1 Chan Fail
DDB #317
Aid 2 Chan Fail
DDB #318
F out of Range
DDB #319
1
General Alarm
part of General Alarm >> page 4
Page 3


CB2 Fail Alarm
DDB #320
CB2 Status Alm
DDB #323
CB2 Monitor Alm
DDB #321
CB2 Mon LO Alarm
DDB #322
NoCS CB2ManClose
DDB #327
CB2 AR Lockout
DDB #328
AR CB2 No C/S
DDB #330
CB2 Trip Fail
DDB #324
CB2 Close Fail
DDB #325
ManCB2 Unhealthy
DDB #326
InValid Mesg Fmt
DDB #333
Main Prot. Fail
DDB #334
Comms Changed
DDB #337
Battery Fail
DDB #352
Field Volts Fail
DDB #353
Max Prop. Alarm
DDB #338
1
500
Dwell
0
Output R4
DDB #003
General Alarm
>>page 3 part of General Alarm
Page 4


100
Dwell
0
Output R12
DDB #011
CB2 Trip OutputA
DDB #1601
100
Dwell
0
Output R18
DDB #017
100
Dwell
0
Output R13
DDB #012
Trip Outputs are generated by the internal single/three phase trip conversion logic.
CB2 Trip OutputB
DDB #1602
100
Dwell
0
Output R19
DDB #018
100
Dwell
0
Output R14
DDB #013
CB2 Trip OutputC
DDB #1603
100
Dwell
0
Output R20
DDB #019
Page 5

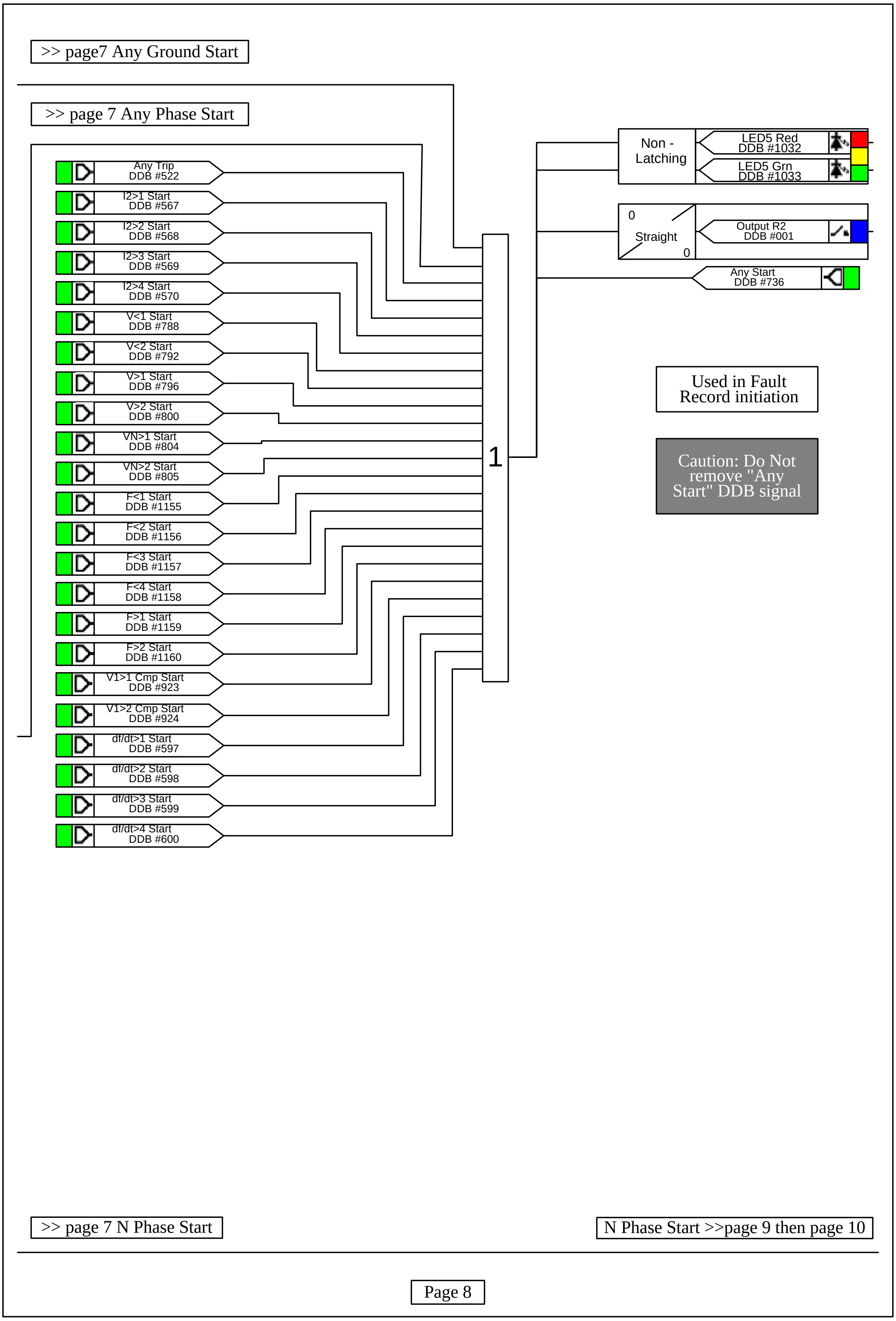

Zone 1 A Start DDB #741
Zone 2 A Start DDB #745
Zone 3 A Start DDB #749
Zone P A Start DDB #753
Zone 4 A Start DDB #757
I>1 Start A DDB #762
I>2 Start A DDB #766
I>3 Start A DDB #770
I>4 Start A DDB #774
1
Start Phase Mappings. Used in Fault Record & on LCD Display
Started Phase A DDB #956
Caution: Do Not remove "Started Phase" DDB signals
Zone 1 B Start DDB #742
Zone 2 B Start DDB #746
Zone 3 B Start DDB #750
Zone P B Start DDB #754
Zone 4 B Start DDB #758
I>1 Start B DDB #763
I>2 Start B DDB #767
I>3 Start B DDB #771
I>4 Start B DDB #775
1
1
Any Phase Start >>page7
Started Phase B DDB #957
>>page 6 Any Phase Start
Zone 1 C Start DDB #743
Zone 2 C Start DDB #747
Zone 3 C Start DDB #751
Zone P C Start DDB #755
Zone 4 C Start DDB #759
I>1 Start C DDB #764
I>2 Start C DDB #768
I>3 Start C DDB #772
I>4 Start C DDB #776
1
Started Phase C DDB #958
Page 6

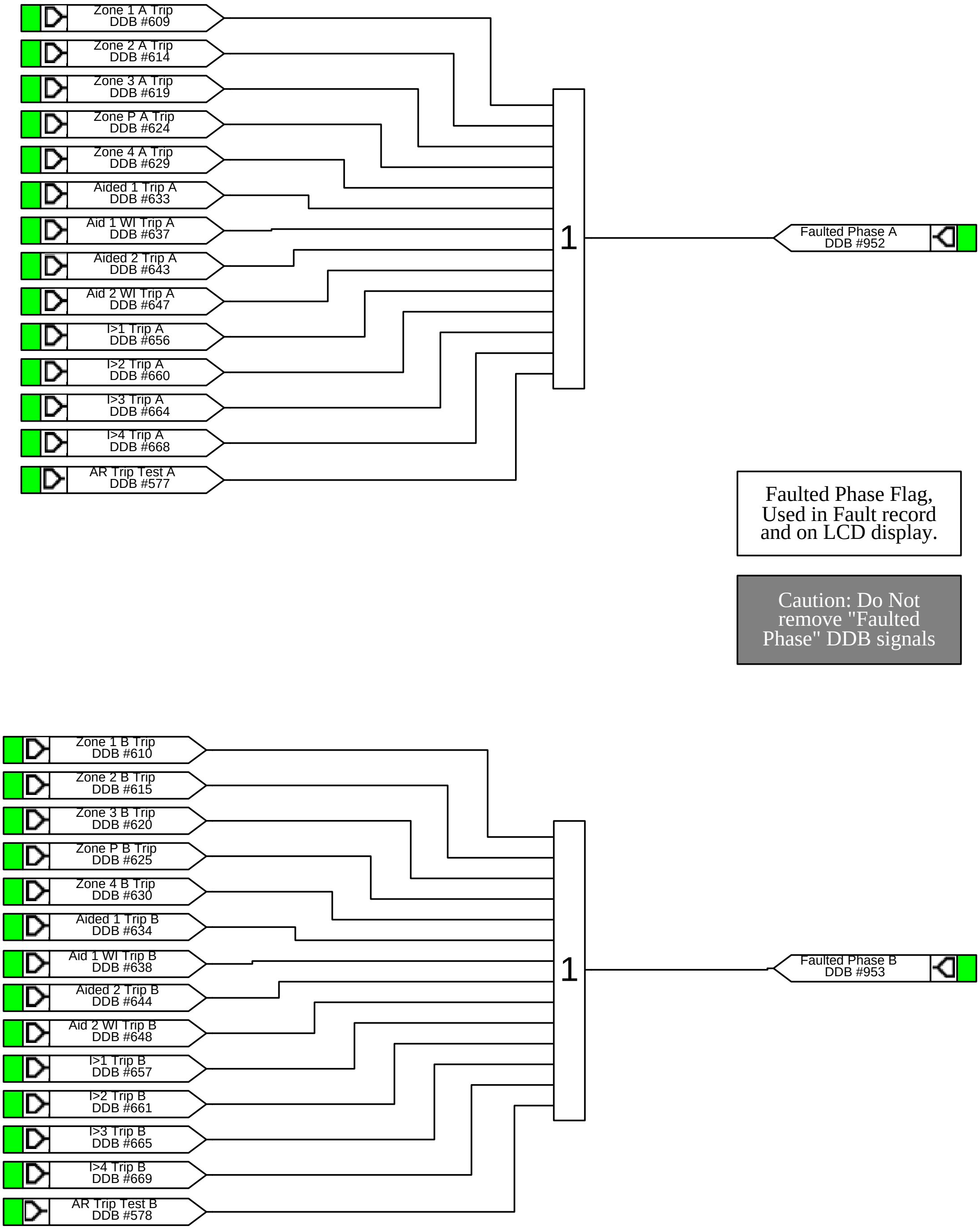

Zone 1 N Start DDB #744
Zone 2 N Start DDB #748
Zone 3 N Start DDB #752
Zone P N Start DDB #756
Zone 4 N Start DDB #760
IN>1 Start DDB #777
IN>2 Start DDB #778
IN>3 Start DDB #779
IN>4 Start DDB #780
ISEF>1 Start DDB #781
ISEF>2 Start DDB #782
ISEF>3 Start DDB #783
ISEF>4 Start DDB #784
Phase Select N DDB #1013
Any Trip DDB #522
&
1
Started Phase N DDB #959
Any Ground Start >> page8
>>page 6 Any Phase Start
Any Phase Start >> page8
Phase Select N DDB #1013
Any Trip DDB #522
10
Pulse
0
&
N Phase Start >> page 8 then page 9 then page 10
AR In Service DDB #1385
Input L5 DDB #036
&
1
Reset Relays/LED DDB #444
Page 7

This logic ensures correct N indications for faults involving ground. The pulse prevents pole scatter affecting the N indication.

This logic clears all latched indications at the start of Any Trip

This reset controls: Reset latched relays, Reset latched LEDs.


>> page7 Any Ground Start
>> page 7 Any Phase Start
Any Trip DDB #522
I2>1 Start DDB #567
I2>2 Start DDB #568
I2>3 Start DDB #569
I2>4 Start DDB #570
V<1 Start DDB #788
V<2 Start DDB #792
V>1 Start DDB #796
V>2 Start DDB #800
VN>1 Start DDB #804
VN>2 Start DDB #805
F<1 Start DDB #1155
F<2 Start DDB #1156
F<3 Start DDB #1157
F<4 Start DDB #1158
F>1 Start DDB #1159
F>2 Start DDB #1160
V1>1 Cmp Start DDB #923
V1>2 Cmp Start DDB #924
df/dt>1 Start DDB #597
df/dt>2 Start DDB #598
df/dt>3 Start DDB #599
df/dt>4 Start DDB #600
1
Non - Latching
LED5 Red DDB #1032
LED5 Grn DDB #1033
0
Straight
0
Output R2 DDB #001
Any Start DDB #736
Used in Fault Record initiation
Caution: Do Not remove "Any Start" DDB signal
>> page 7 N Phase Start
N Phase Start >>page 9 then page 10
Page 8

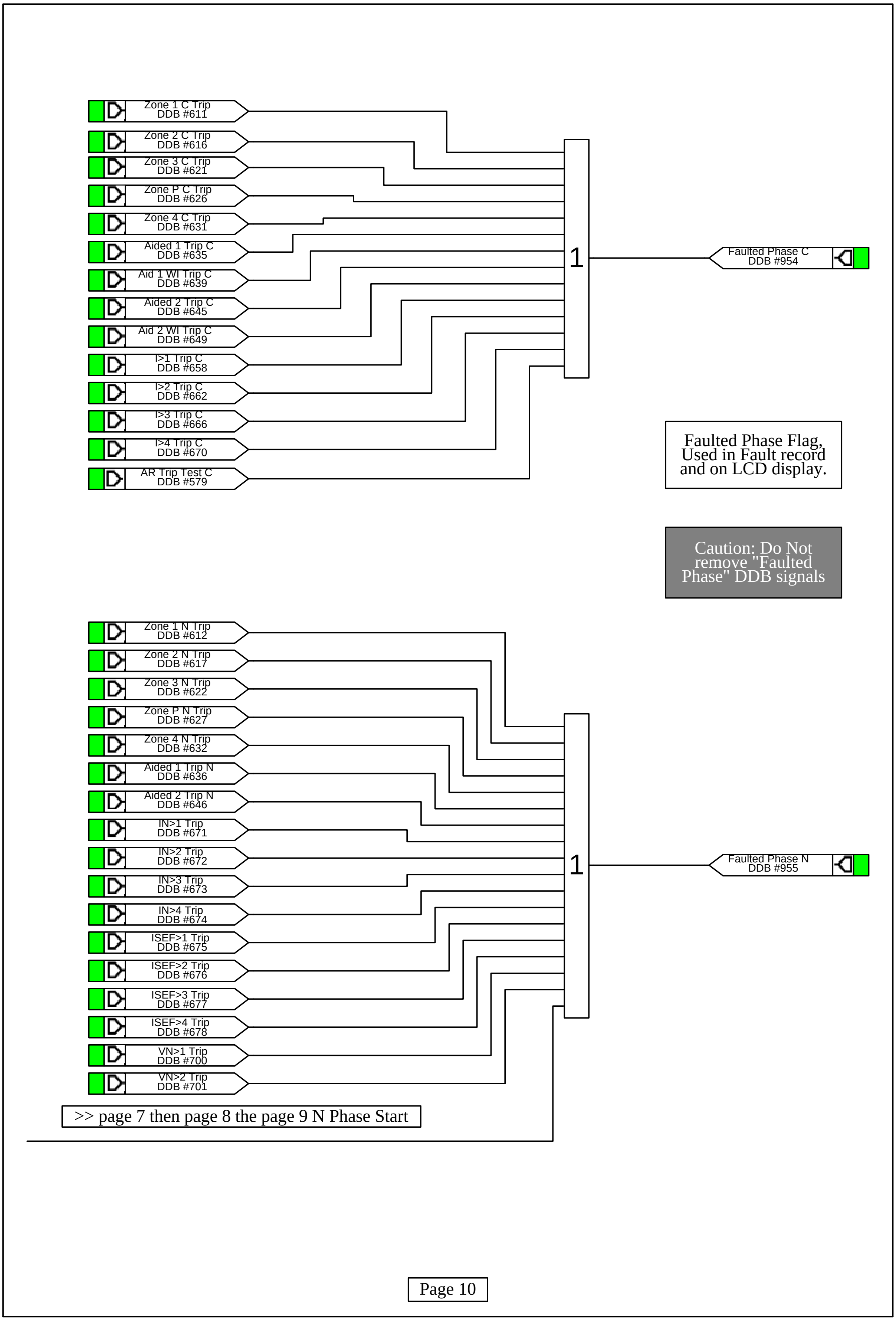

Zone 1 A Trip DDB #609
Zone 2 A Trip DDB #614
Zone 3 A Trip DDB #619
Zone P A Trip DDB #624
Zone 4 A Trip DDB #629
Aided 1 Trip A DDB #633
Aid 1 WI Trip A DDB #637
Aided 2 Trip A DDB #643
Aid 2 WI Trip A DDB #647
I>1 Trip A DDB #656
I>2 Trip A DDB #660
I>3 Trip A DDB #664
I>4 Trip A DDB #668
AR Trip Test A DDB #577
1
Faulted Phase A DDB #952
Zone 1 B Trip DDB #610
Zone 2 B Trip DDB #615
Zone 3 B Trip DDB #620
Zone P B Trip DDB #625
Zone 4 B Trip DDB #630
Aided 1 Trip B DDB #634
Aid 1 WI Trip B DDB #638
Aided 2 Trip B DDB #644
Aid 2 WI Trip B DDB #648
I>1 Trip B DDB #657
I>2 Trip B DDB #661
I>3 Trip B DDB #665
I>4 Trip B DDB #669
AR Trip Test B DDB #578
1
Faulted Phase B DDB #953

Faulted Phase Flag, Used in Fault record and on LCD display.

Caution: Do Not remove "Faulted Phase" DDB signals

>> page 7 then page 8 N Phase Start

N Phase Start >> page 10

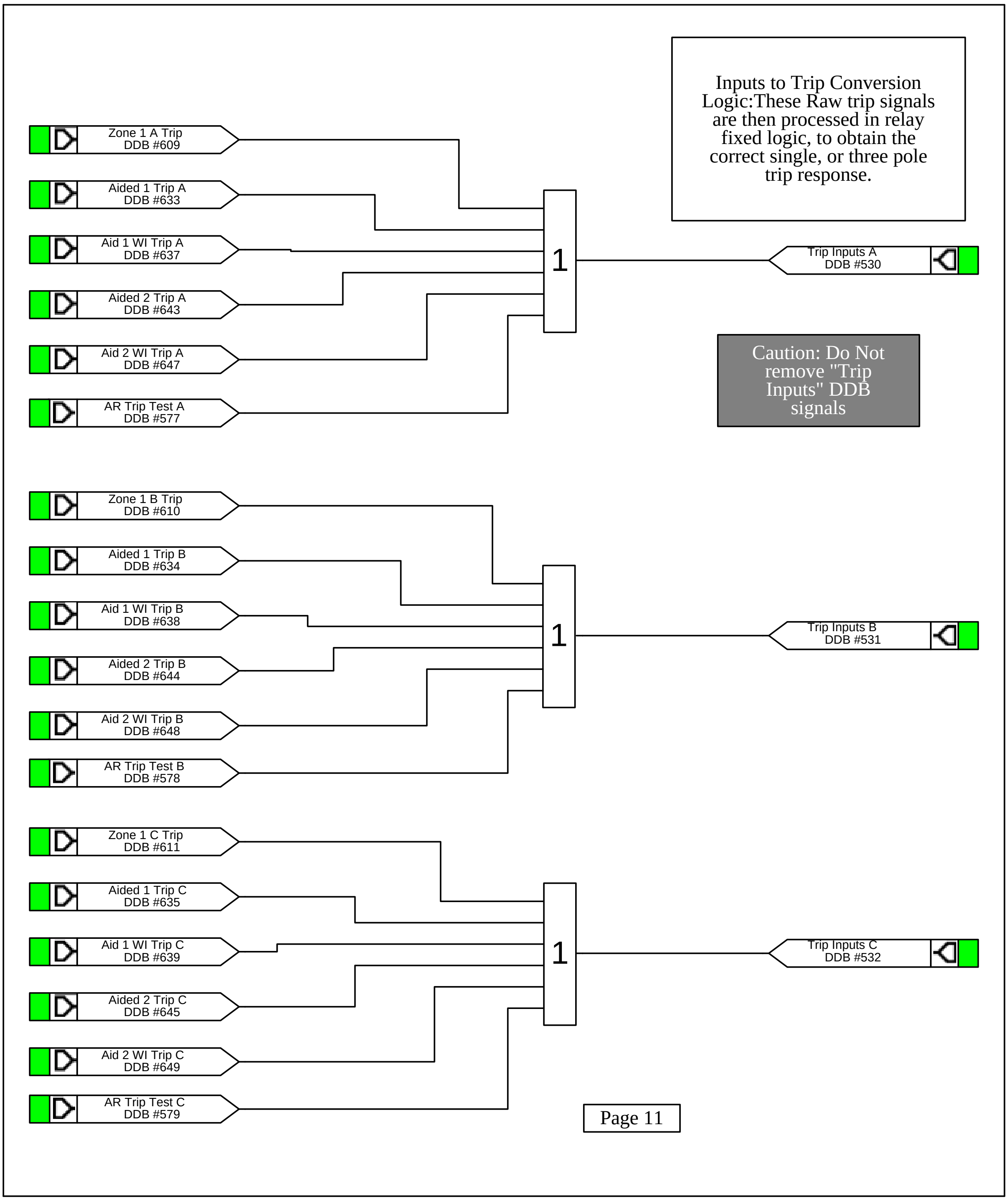

Zone 1 C Trip DDB #611
Zone 2 C Trip DDB #616
Zone 3 C Trip DDB #621
Zone P C Trip DDB #626
Zone 4 C Trip DDB #631
Aided 1 Trip C DDB #635
Aid 1 WI Trip C DDB #639
Aided 2 Trip C DDB #645
Aid 2 WI Trip C DDB #649
I>1 Trip C DDB #658
I>2 Trip C DDB #662
I>3 Trip C DDB #666
I>4 Trip C DDB #670
AR Trip Test C DDB #579
1
Faulted Phase C DDB #954
Zone 1 N Trip DDB #612
Zone 2 N Trip DDB #617
Zone 3 N Trip DDB #622
Zone P N Trip DDB #627
Zone 4 N Trip DDB #632
Aided 1 Trip N DDB #636
Aided 2 Trip N DDB #646
IN>1 Trip DDB #671
IN>2 Trip DDB #672
IN>3 Trip DDB #673
IN>4 Trip DDB #674
ISEF>1 Trip DDB #675
ISEF>2 Trip DDB #676
ISEF>3 Trip DDB #677
ISEF>4 Trip DDB #678
VN>1 Trip DDB #700
VN>2 Trip DDB #701
1
Faulted Phase N DDB #955

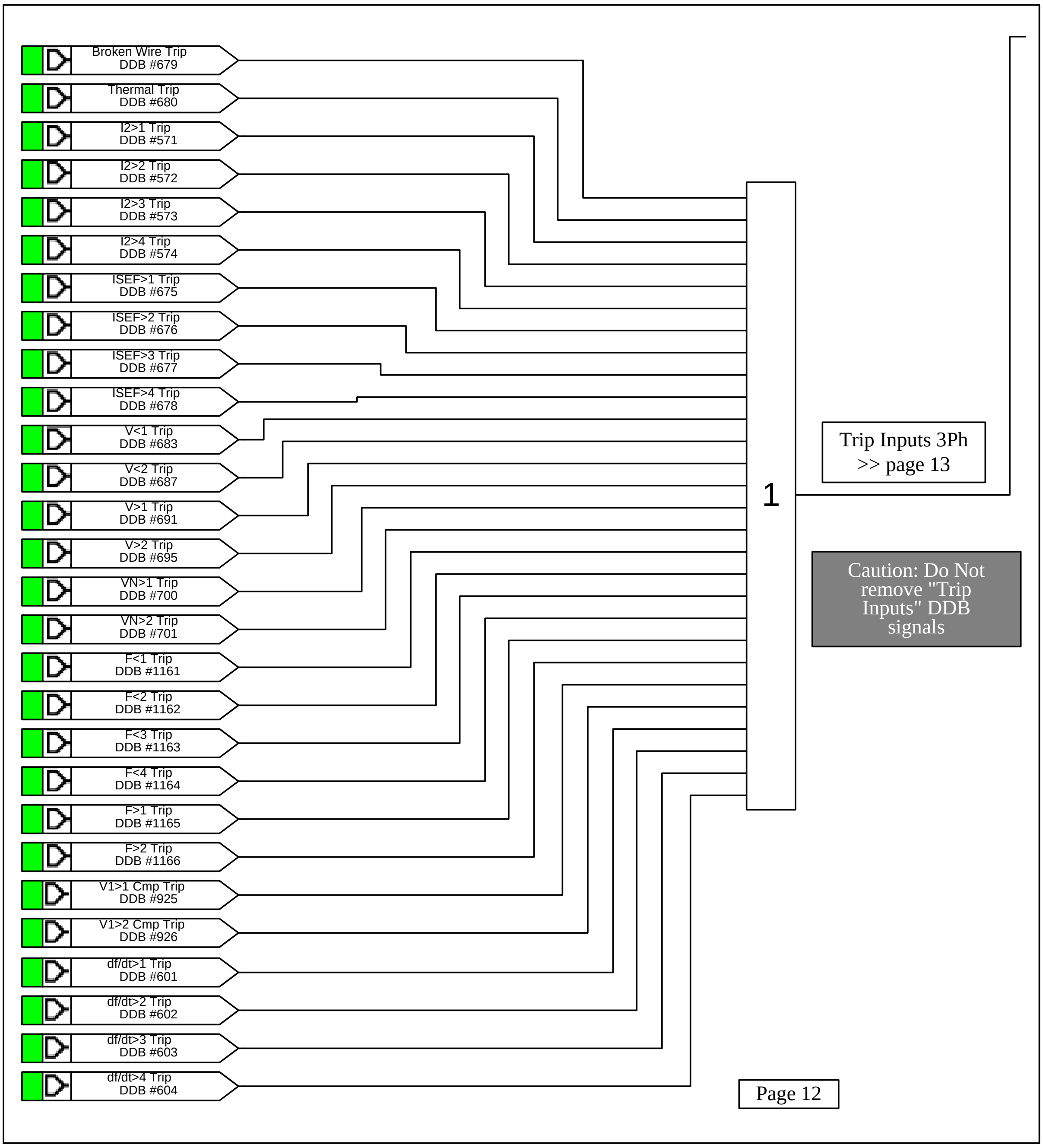
Faulted Phase Flag, Used in Fault record and on LCD display.

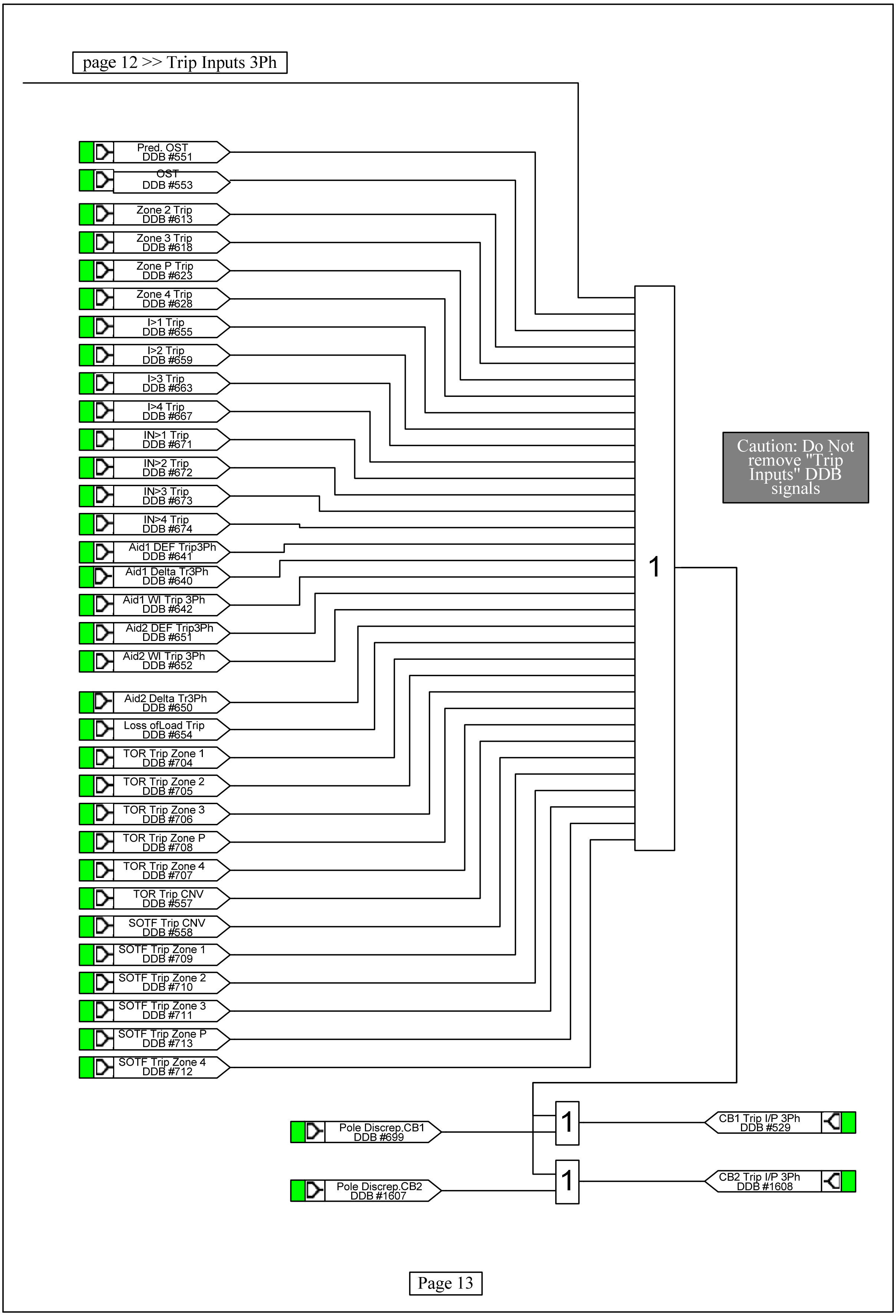
Caution: Do Not remove "Faulted Phase" DDB signals

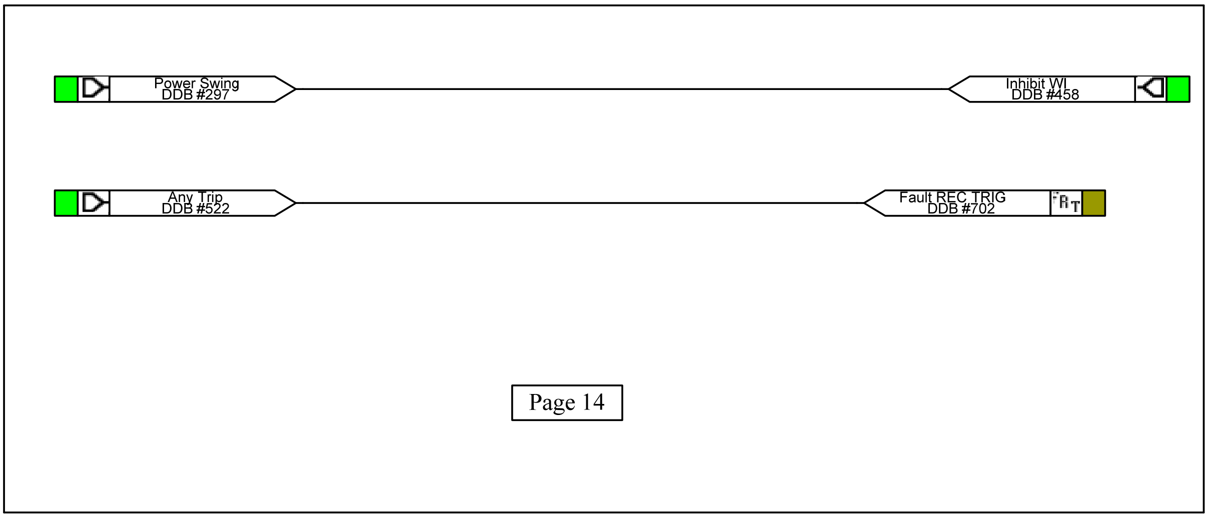
>> page 7 then page 8 the page 9 N Phase Start

Page 10

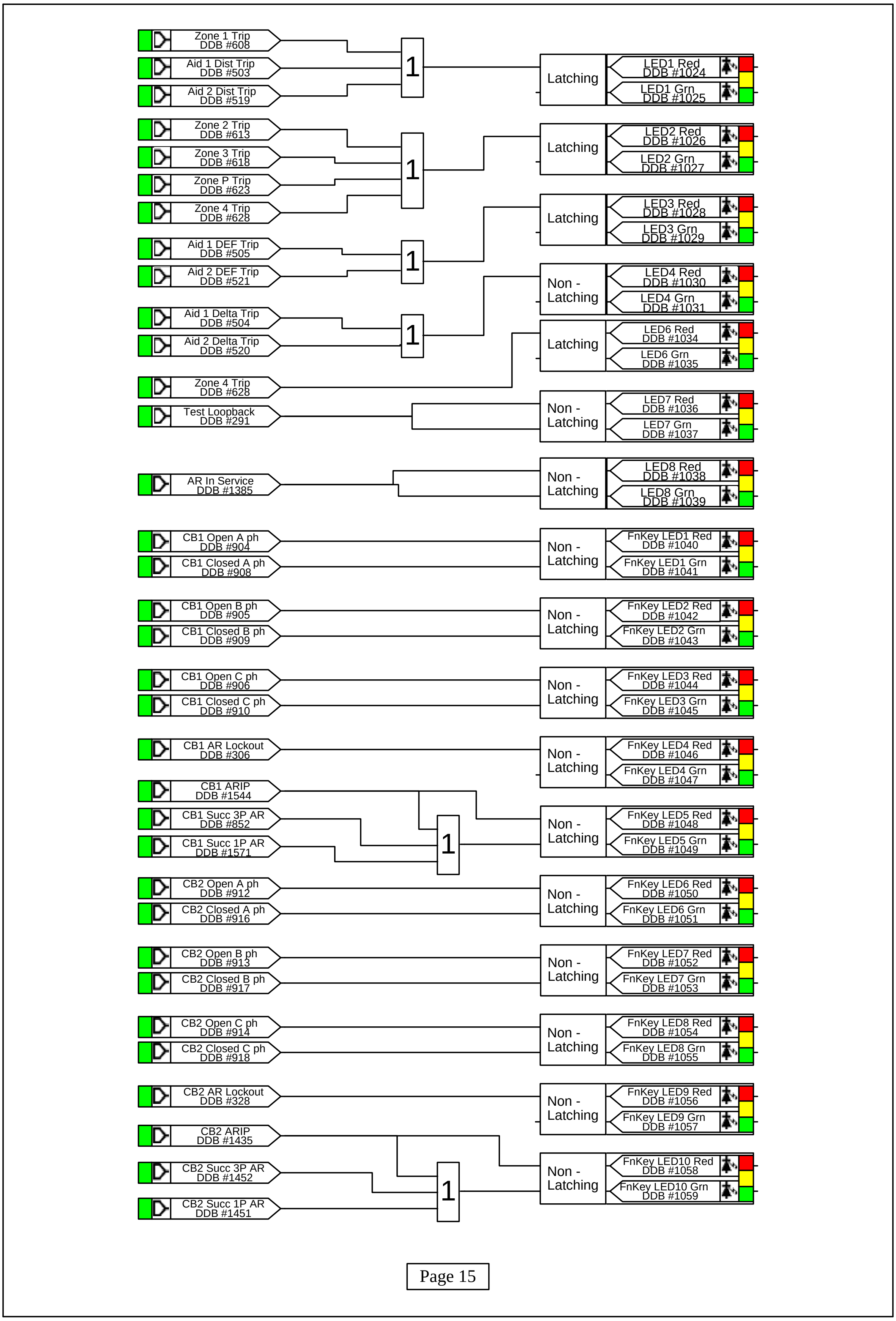

Inputs to Trip Conversion Logic:These Raw trip signals are then processed in relay fixed logic, to obtain the correct single, or three pole trip response.
Zone 1 A Trip DDB #609
Aided 1 Trip A DDB #633
Aid 1 WI Trip A DDB #637
Aided 2 Trip A DDB #643
Aid 2 WI Trip A DDB #647
AR Trip Test A DDB #577
1
Trip Inputs A DDB #530
Caution: Do Not remove "Trip Inputs" DDB signals
Zone 1 B Trip DDB #610
Aided 1 Trip B DDB #634
Aid 1 WI Trip B DDB #638
Aided 2 Trip B DDB #644
Aid 2 WI Trip B DDB #648
AR Trip Test B DDB #578
1
Trip Inputs B DDB #531
Zone 1 C Trip DDB #611
Aided 1 Trip C DDB #635
Aid 1 WI Trip C DDB #639
Aided 2 Trip C DDB #645
Aid 2 WI Trip C DDB #649
AR Trip Test C DDB #579
1
Trip Inputs C DDB #532
Page 11


Broken Wire Trip DDB #679
Thermal Trip DDB #680
I2>1 Trip DDB #571
I2>2 Trip DDB #572
I2>3 Trip DDB #573
I2>4 Trip DDB #574
ISEF>1 Trip DDB #675
ISEF>2 Trip DDB #676
ISEF>3 Trip DDB #677
ISEF>4 Trip DDB #678
V<1 Trip DDB #683
V<2 Trip DDB #687
V>1 Trip DDB #691
V>2 Trip DDB #695
VN>1 Trip DDB #700
VN>2 Trip DDB #701
F<1 Trip DDB #1161
F<2 Trip DDB #1162
F<3 Trip DDB #1163
F<4 Trip DDB #1164
F>1 Trip DDB #1165
F>2 Trip DDB #1166
V1>1 Cmp Trip DDB #925
V1>2 Cmp Trip DDB #926
df/dt>1 Trip DDB #601
df/dt>2 Trip DDB #602
df/dt>3 Trip DDB #603
df/dt>4 Trip DDB #604
1
Trip Inputs 3Ph >> page 13
Caution: Do Not remove "Trip Inputs" DDB signals
Page 12


page 12 >> Trip Inputs 3Ph
Pred. OST DDB #551
OST DDB #553
Zone 2 Trip DDB #613
Zone 3 Trip DDB #618
Zone P Trip DDB #623
Zone 4 Trip DDB #628
I>1 Trip DDB #655
I>2 Trip DDB #659
I>3 Trip DDB #663
I>4 Trip DDB #667
IN>1 Trip DDB #671
IN>2 Trip DDB #672
IN>3 Trip DDB #673
IN>4 Trip DDB #674
Aid1 DEF Trip3Ph DDB #641
Aid1 Delta Tr3Ph DDB #640
Aid1 WI Trip 3Ph DDB #642
Aid2 DEF Trip3Ph DDB #651
Aid2 WI Trip 3Ph DDB #652
Aid2 Delta Tr3Ph DDB #650
Loss ofLoad Trip DDB #654
TOR Trip Zone 1 DDB #704
TOR Trip Zone 2 DDB #705
TOR Trip Zone 3 DDB #706
TOR Trip Zone P DDB #708
TOR Trip Zone 4 DDB #707
TOR Trip CNV DDB #557
SOTF Trip CNV DDB #558
SOTF Trip Zone 1 DDB #709
SOTF Trip Zone 2 DDB #710
SOTF Trip Zone 3 DDB #711
SOTF Trip Zone P DDB #713
SOTF Trip Zone 4 DDB #712
1
Caution: Do Not remove "Trip Inputs" DDB signals
Pole Discrep.CB1 DDB #699
Pole Discrep.CB2 DDB #1607
1
1
CB1 Trip I/P 3Ph DDB #529
CB2 Trip I/P 3Ph DDB #1608
Page 13


Power Swing
DDB #297
Inhibit WI
DDB #458
Any Trip
DDB #522
Fault REC TRIG
DDB #702
Page 14

LEDs



Zone 1 Trip DDB #608
Aid 1 Dist Trip DDB #503
Aid 2 Dist Trip DDB #519
Zone 2 Trip DDB #613
Zone 3 Trip DDB #618
Zone P Trip DDB #623
Zone 4 Trip DDB #628
Aid 1 DEF Trip DDB #505
Aid 2 DEF Trip DDB #521
Aid 1 Delta Trip DDB #504
Aid 2 Delta Trip DDB #520
Zone 4 Trip DDB #628
Test Loopback DDB #291
AR In Service DDB #1385
CB1 Open A ph DDB #904
CB1 Closed A ph DDB #908
CB1 Open B ph DDB #905
CB1 Closed B ph DDB #909
CB1 Open C ph DDB #906
CB1 Closed C ph DDB #910
CB1 AR Lockout DDB #306
CB1 ARIP DDB #1544
CB1 Succ 3P AR DDB #852
CB1 Succ 1P AR DDB #1571
CB2 Open A ph DDB #912
CB2 Closed A ph DDB #916
CB2 Open B ph DDB #913
CB2 Closed B ph DDB #917
CB2 Open C ph DDB #914
CB2 Closed C ph DDB #918
CB2 AR Lockout DDB #328
CB2 ARIP DDB #1435
CB2 Succ 3P AR DDB #1452
CB2 Succ 1P AR DDB #1451
1
1
1
1
1
1
Latching
Latching
Latching
Non - Latching
Latching
Non - Latching
Non - Latching
Non - Latching
Non - Latching
Non - Latching
Non - Latching
Non - Latching
Non - Latching
Non - Latching
Non - Latching
Non - Latching
Non - Latching
LED1 Red DDB #1024
LED1 Grn DDB #1025
LED2 Red DDB #1026
LED2 Grn DDB #1027
LED3 Red DDB #1028
LED3 Grn DDB #1029
LED4 Red DDB #1030
LED4 Grn DDB #1031
LED6 Red DDB #1034
LED6 Grn DDB #1035
LED7 Red DDB #1036
LED7 Grn DDB #1037
LED8 Red DDB #1038
LED8 Grn DDB #1039
FnKey LED1 Red DDB #1040
FnKey LED1 Grn DDB #1041
FnKey LED2 Red DDB #1042
FnKey LED2 Grn DDB #1043
FnKey LED3 Red DDB #1044
FnKey LED3 Grn DDB #1045
FnKey LED4 Red DDB #1046
FnKey LED4 Grn DDB #1047
FnKey LED5 Red DDB #1048
FnKey LED5 Grn DDB #1049
FnKey LED6 Red DDB #1050
FnKey LED6 Grn DDB #1051
FnKey LED7 Red DDB #1052
FnKey LED7 Grn DDB #1053
FnKey LED8 Red DDB #1054
FnKey LED8 Grn DDB #1055
FnKey LED9 Red DDB #1056
FnKey LED9 Grn DDB #1057
FnKey LED10 Red DDB #1058
FnKey LED10 Grn DDB #1059
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Notes:

MEASUREMENTS AND RECORDING

CHAPTER 8

Date:	02/2013
Hardware Suffix:	M
Software Version:	D0
Connection Diagrams:	10P44303 (SH 01 and 03) 10P44304 (SH 01 and 03) 10P44305 (SH 01 and 03) 10P44306 (SH 01 and 03) 10P44600 10P44601 (SH 1 to 2) 10P44602 (SH 1 to 2) 10P44603 (SH 1 to 2)

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1 INTRODUCTION

The P443/P446 is equipped with integral measurements, event, fault and disturbance recording facilities suitable for analysis of complex system disturbances.

The relay is flexible enough to allow for the programming of these facilities to specific user application requirements and are discussed below.

2 EVENT AND FAULT RECORDS

The relay records and time tags up to 512 events and stores them in non-volatile (battery backed up) memory. This enables the system operator to establish the sequence of events that occurred within the relay following a particular power system condition, switching sequence etc. When the available space is exhausted, the oldest event is automatically overwritten by the new one.

The real time clock within the relay provides the time tag to each event, to a resolution of 1ms.

The event records are available for viewing either via the frontplate LCD or remotely, via the communications ports (courier versions only).

Local viewing on the LCD is achieved in the menu column entitled "VIEW RECORDS". This column allows viewing of event, fault and maintenance records and is shown in Table 1:

VIEW RECORDS	
LCD Reference	**Description**
Select Event	Setting range from 0 to 511. This selects the required event record from the possible 512 that may be stored. A value of 0 corresponds to the latest event and so on.
Time & Date	Time & Date Stamp for the event given by the internal Real Time Clock.
Event Text	Up to 32 Character description of the Event (refer to following sections).
Event Value	Up to 32 Bit Binary Flag or integer representative of the Event (refer to following sections).
Select Fault	Setting range from 0 to 14. This selects the required fault record from the possible 15 that may be stored. A value of 0 corresponds to the latest fault and so on.
	The following cells show all the fault flags, protection starts, protection trips, fault location, measurements etc. associated with the fault, i.e. the complete fault record.
Select Maint.	Setting range from 0 to 9. This selects the required maintenance report from the possible 10 that may be stored. A value of 0 corresponds to the latest report and so on.
Maint. Text	Up to 16 Character description of the occurrence (refer to following sections).
Maint. Type/Main Data	These cells are numbers representative of the occurrence. They form a specific error code which should be quoted in any related correspondence to Report Data.
Reset Indication	Either Yes or No. This serves to reset the trip LED indications provided that the relevant protection element has reset.

Table 1 – View records

For extraction from a remote source via communications, refer to the SCADA Communications section (P44y/EN SC), where the procedure is fully explained.

2.1 Types of Event

An event may be a change of state of a control input or output relay, an alarm condition, setting change etc. The following sections show the various items that constitute an event:

2.1.1 Change of State of Opto-Isolated Inputs

If one or more of the opto (logic) inputs has changed state since the last time that the protection algorithm ran, the new status is logged as an event. When this event is selected to be viewed on the LCD, three applicable cells will become visible as shown below:

Time & date of event
“LOGIC INPUTS 1”
“Event Value 0101010101010101”

Table 2 – Logic inputs

The Event Value is an 8, 12, 16 or 24-bit word showing the status of the opto inputs, where the least significant bit (extreme right) corresponds to opto input 1 etc. The same information is present if the event is extracted and viewed via PC.

2.1.2 Change of State of one or more Output Relay Contacts

If one or more of the output relay contacts have changed state since the last time that the protection algorithm ran, then the new status is logged as an event. When this event is selected to be viewed on the LCD, three applicable cells will become visible as shown below:

Time & date of event
“OUTPUT CONTACTS 1”
“Event Value 010101010101010101010”

Table 3 – Output contacts

The Event Value is an 8, 12, 16, 24 or 32 bit word showing the status of the output contacts, where the least significant bit (extreme right) corresponds to output contact 1 etc. The same information is present if the event is extracted and viewed via PC.

2.1.3 Relay Alarm Conditions

Any alarm conditions generated by the relays will also be logged as individual events. Table 4 shows examples of some of the alarm conditions and how they appear in the event list:

Alarm Condition	Event Text	Event Value
Battery Fail	Battery Fail ON/OFF	Bit position 0 in 32 bit field
Field Voltage Fail	Field Volt Fail ON/OFF	Bit position 1 in 32 bit field
Setting Group via Opto Invalid	Setting Grp. Invalid ON/OFF	Bit position 2 in 32 bit field
Protection Disabled	Prot’n. Disabled ON/OFF	Bit position 3 in 32 bit field
Frequency out of Range	Freq. out of Range ON/OFF	Bit position 4 in 32 bit field
VTS Alarm	VT Fail Alarm ON/OFF	Bit position 5 in 32 bit field
CB Trip Fail Protection	CB Fail ON/OFF	Bit position 7 in 32 bit field

Table 4 – Alarm conditions

The previous table shows the abbreviated description that is given to the various alarm conditions and also a corresponding value between 0 and 31. This value is appended to each alarm event in a similar way as for the input and output events previously described. It is used by the event extraction software, such as MiCOM S1, to identify the alarm and is therefore invisible if the event is viewed on the LCD. Either ON or OFF is shown after the description to signify whether the particular condition has become operated or has reset.

2.1.4 Protection Element Starts and Trips

Any operation of protection elements, (either a start or a trip condition) will be logged as an event record, consisting of a text string indicating the operated element and an event value. Again, this value is intended for use by the event extraction software, such as MiCOM S1, rather than for the user, and is therefore invisible when the event is viewed on the LCD.

2.1.5 General Events

A number of events come under the heading of ‘General Events’ - an example is shown in Table 5:

Nature of Event	Displayed Text in Event Record	Displayed Value
Level 1 password modified, either from user interface, front or rear port.	PW1 modified UI, F, R or R2	0 UI=6, F=11, R=16, R2=38

Table 5 – General events

A complete list of the ‘General Events’ is given in the Relay Menu Database (P44y/EN MD), which is a separate document, available for downloading from our website.

2.1.6 Fault Records

Each time a fault record is generated, an event is also created. The event simply states that a fault record was generated, with a corresponding time stamp.

Note *Viewing of the actual fault record is carried out in the "Select Fault’" cell further down the "VIEW RECORDS" column, which is selectable from up to 15 records. These records consist of fault flags, fault location, fault measurements etc. Also note that the time stamp given in the fault record itself will be more accurate than the corresponding stamp given in the event record as the event is logged some time after the actual fault record is generated.*

The fault record is triggered from the ‘Fault REC. TRIG.’ signal assigned in the default programmable scheme logic to relay 3, protection trip.

Note *The fault measurements in the fault record are given at the time of the protection start. Also, the fault recorder does not stop recording until any start or relay 3 (protection trip) resets in order to record all the protection flags during the fault.*

It is recommended that the triggering contact (relay 3 for example) be ‘self reset’ and not latching. If a latching contact were chosen the fault record would not be generated until the contact had fully reset.

2.1.7 Maintenance Reports

Internal failures detected by the self-monitoring circuitry, such as watchdog failure, field voltage failure etc. are logged into a maintenance report. The maintenance report holds up to 10 such 'events' and is accessed from the "Select Report" cell at the bottom of the "VIEW RECORDS" column.

Each entry consists of a self explanatory text string and a 'Type' and 'Data' cell, which are explained in the menu extract at the beginning of this section.

Each time a Maintenance Report is generated, an event is also created. The event simply states that a report was generated, with a corresponding time stamp.

2.1.8 Setting Changes

Changes to any setting within the relay are logged as an event. Two examples are shown in Table 6:

Type of Setting Change	Displayed Text in Event Record	Displayed Value
Control/Support Setting	C & S Changed	22
Group # Change	Group # Changed	#
Where # = 1 to 4		

Table 6 – Setting changes

Note *Control/Support settings are communications, measurement, CT/VT ratio settings etc, which are not duplicated within the four setting groups. When any of these settings are changed, the event record is created simultaneously. However, changes to protection or disturbance recorder settings will only generate an event once the settings have been confirmed at the 'setting trap'.*

2.2 Resetting of Event/Fault Records

If it is required to delete either the event, fault or maintenance reports, this may be done from within the "RECORD CONTROL" column.

2.3 Viewing Event Records via MiCOM S1 Support Software

When the event records are extracted and viewed on a PC they look slightly different than when viewed on the LCD. The following shows an example of how various events appear when displayed using MiCOM S1:

Monday 27 October 2008 15:32:49 GMT I>1 Start ON

MiCOM: MiCOM P443

Model Number: P443218A1M0540K

Address: 001 Column: 00 Row: 23

Event Type: Protection operation

Monday 27 October 2008 15:32:52 GMT Fault Recorded

MiCOM: MiCOM P443

Model Number: P443218A1M0540K

Address: 001 Column: 01 Row: 00

Event Type: Fault record

Monday 27 October 2008 15:33:11 GMT Logic Inputs

MiCOM: MiCOM P443

Model Number: P443218A1M0540K

Address: 001 Column: 00 Row: 20

Event Type: Logic input changed state

Monday 27 October 2008 15:34:54 GMT Output Contacts

MiCOM: MiCOM P443

Model Number: P443218A1M0540K

Address: 001 Column: 00 Row: 21

Event Type: Relay output changed state

Monday 27 October 2008 15:35:55 GMT A/R Lockout ON

MiCOM: MiCOM P443

Model Number: P443218A1M0540K

Address: 001 Column: 00 Row: 22

Event Type: Alarm event

Tuesday 28 October 2008 20:18:22.988 GMT Zone 1 Trip ON

MiCOM: MiCOM P443

Model Number: P443218A1M0540K

Address: 001 Column: 0F Row: 30

Event Type: Setting event

As can be seen, the first line gives the description and time stamp for the event, whilst the additional information that is displayed below may be collapsed via the +/– symbol.
For further information regarding events and their specific meaning, refer to relay menu database document (P44y/EN MD). This is a standalone document not included in this manual.

2.4 Event Filtering

It is possible to disable the reporting of events from all interfaces that supports setting changes. The settings that control the various types of events are in the record control column. The effect of setting each to disabled is shown in Table 7:

Menu Text	Default Setting	Available Settings
Clear Event	No	No or Yes
Selecting “Yes” will cause the existing event log to be cleared and an event will be generated indicating that the events have been erased.		
Clear Faults	No	No or Yes
Selecting “Yes” will cause the existing fault records to be erased from the relay.		
Clear Maint.	No	No or Yes
Selecting “Yes” will cause the existing maintenance records to be erased from the relay.		
Alarm Event	Enabled	Enabled or Disabled
Disabling this setting means that all the occurrences that produce an alarm will result in no event being generated.		
Relay O/P Event	Enabled	Enabled or Disabled
Disabling this setting means that no event will be generated for any change in logic input state.		
Opto Input Event	Enabled	Enabled or Disabled
Disabling this setting means that no event will be generated for any change in logic input state.		
General Event	Enabled	Enabled or Disabled
Disabling this setting means that no General Events will be generated.		
Fault Rec. Event	Enabled	Enabled or Disabled
Disabling this setting means that no event will be generated for any fault that produces a fault record.		
Maint. Rec. Event	Enabled	Enabled or Disabled
Disabling this setting means that no event will be generated for any occurrence that produces a maintenance record.		
Protection Event	Enabled	Enabled or Disabled
Disabling this setting means that any operation of protection elements will not be logged as an event.		
DDB 31 - 0	11111111111111111111111111111111	
Displays the status of DDB signals 0 - 31.		
DDB 1791 - 1760	11111111111111111111111111111111	
Displays the status of DDB signals 1791 - 1760.		
Note *Some occurrences will result in more than one type of event, e.g. a battery failure will produce an alarm event and a maintenance record event.*		

Table 7 – Event filtering

If the **Protection Event** setting is **Enabled** a further set of settings is revealed which allow the event generation by individual DDB signals to be enabled or disabled.

For further information regarding events and their specific meaning, refer to relay menu database document (P44y/EN MD).

3 ENHANCED DISTURBANCE RECORDER

> *Note* *The disturbance recorder setting options were changed with Software Version B0 and again with D0. Therefore models with the B0 or D0 software may have different settings to previous models.*

The integral enhanced disturbance recorder has an area of memory specifically set aside for record storage. The number of records that may be stored by the relay is dependent on the selected recording duration and the installed software release.

- The relay can typically store a minimum of 15 records, each of 1.5 seconds duration.
- Relays for use with IEC 60870-5 CS 103 communication, however, have the same total record length but the IEC 60870-5 CS 103 communication protocol dictates that only 8 records (of 3 seconds duration) can be extracted via the rear port.

Disturbance records continue to be recorded until the available memory is exhausted, at which time the oldest record(s) are overwritten to make space for the newest one.

The recorder stores actual samples that are taken at a rate of 48 samples per cycle.

Each disturbance record consists of 20 analog data channels and 128 digital data channels. The relevant CT and VT ratios for the analog channels are also extracted to enable scaling to primary quantities.

Note *If a CT ratio is set less than unity, the relay will choose a scaling factor of zero for the appropriate channel.*

The "DISTURBANCE RECORDER" menu column is shown in Table 8:

Menu Text	**Default Setting**	**Setting Range**		**Step Size**
		Min.	**Max.**	
DISTURB. RECORDER				
Duration	1.5 s	0.1 s	10.5 s	0.01 s
This sets the overall recording time.				
Trigger Position	33.3%	0	100.0%	0.1%
This sets the trigger point as a percentage of the duration. For example, the default settings show that the overall recording time is set to 3.0 s with the trigger point being at 33.3% of this, giving 1.0 s pre-fault and 1s post fault recording times.				
Trigger Mode	Single		Single or Extended	
If set to single mode, if a further trigger occurs whilst a recording is taking place, the recorder will ignore the trigger. However, if this has been set to Extended, the post trigger timer will be reset to zero, thereby extending the recording time.				
Analog. Channel 1	VA	IA, IB, IC, IN, IN Sensitive, VA, VB, VC, IM, V Checksync (P443 and P446) and IA2, IB2, IC2 VChecksync2 (P446 only)		
Selects any available analog input to be assigned to this channel (including derived IN residual current).				
Analog. Channel 2	VB	As above		
Analog. Channel 3	VC	As above		
Analog. Channel 4	IA	As above		
Analog. Channel 5	IB	As above		
Analog. Channel 6	IC	As above		
Analog. Channel 7	IN	As above		
Analog. Channel 8	IN Sensitive	As above		
Digital Inputs 1 to 128	Relays 1 to 12 and Opto's 1 to 12	Any O/P Contact, Any Opto Inputs, or Internal Digital Signals		

Menu Text	Default Setting	Setting Range		Step Size
		Min.	Max.	
The digital channels may monitor any of the opto isolated inputs or output contacts, in addition to a number of internal relay digital signals, such as protection starts, LEDs etc.				
Inputs 1 to 32 Trigger	No Trigger except Dedicated Trip Relay 3 operation which are set to Trigger L/H	No Trigger, Trigger L/H, Trigger H/L		
Any of the digital channels may be selected to trigger the disturbance recorder on either a low-to-high or a high-to-low transition.				
Analog. Channel 9	V Checksync	As above		
Analog. Channel 10	IM (P443) IA2 (P446)	As above		
Analog. Channel 11	IN (P443) IB2 (P446)	As above		
Analog. Channel 12	IN (P443) IC2 (P446)	As above		

Table 8 – Disturbance recorder

The pre and post fault recording times are set by a combination of the **Duration** and **Trigger Position** cells. **Duration** sets the overall recording time and the **Trigger Position** sets the trigger point as a percentage of the duration. For example, the default settings show that the overall recording time is set to 3.0 s with the trigger point being at 16.7% of this, giving 0.5 s pre-fault and 1 s post-fault recording times.

If a further trigger occurs whilst a recording is taking place, the recorder will ignore the trigger if the Trigger Mode has been set to Single. However, if this has been set to Extended, the post trigger timer will be reset to zero, thereby extending the recording time.

As can be seen from the menu, each of the analog channels is selectable from the available analog inputs to the relay. The digital channels may be mapped to any of the opto-isolated inputs or output contacts, in addition to a number of internal relay digital signals, such as protection starts, LEDs etc. The complete list of these signals may be found by viewing the available settings in the relay menu or using a setting file in the S1 Studio software. Any of the digital channels may be selected to trigger the disturbance recorder on either a low-to-high or a high-to-low transition, using the Input Trigger cell. The default trigger settings are that any dedicated trip output contacts (e.g. relay 3) will trigger the recorder.

It is not possible to view the disturbance records locally using the LCD; they must be extracted using suitable software such as S1 Studio software. This process is fully explained in the SCADA Communications chapter.

4 MEASUREMENTS

The relay produces a variety of both directly measured and calculated power system quantities. These measurement values are updated on a per second basis and can be viewed in the “Measurements” columns (up to three) of the relay or via MiCOM S1 Measurement viewer. The P443/P446 relay is able to measure and display the following quantities as summarized:

- Phase Voltages and Currents
- Phase to Phase Voltages and Currents
- Sequence Voltages and Currents
- Slip Frequency
- Power and Energy Quantities
- Rms. Voltages and Currents
- Peak, Fixed and Rolling Demand Values

There are also measured values from the protection functions, which are also displayed under the measurement columns of the menu; these are described in the section on the relevant protection function.

4.1 Measured Voltages and Currents

The relay produces both phase to ground and phase to phase voltage and current values. They are produced directly from the DFT (Discrete Fourier Transform) used by the relay protection functions and present both magnitude and phase angle measurement for each individual CT.

4.2 Sequence Voltages and Currents

Sequence quantities are produced by the relay from the measured Fourier values; these are displayed as magnitude and phase angle values.

4.3 Slip Frequency

The relay produces a slip frequency measurement by measuring the rate of change of phase angle, between the bus and line voltages, over a one-cycle period. The slip frequency measurement assumes the bus voltage to be the reference phasor.

4.4 Power and Energy Quantities

Using the measured voltages and currents the relay calculates the apparent, real and reactive power quantities. These are produced on a phase by phase basis together with three-phase values based on the sum of the three individual phase values. The signing of the real and reactive power measurements can be controlled using the measurement mode setting. The four options are defined in Table 9:

Measurement Mode	Parameter	Signing
0 (Default)	Export Power Import Power Lagging VArs Leading VArs	+ – + –

Measurement Mode	Parameter	Signing
1	Export Power Import Power Lagging VArs Leading VArs	– + + –
2	Export Power Import Power Lagging VArs Leading VArs	+ – – +
3	Export Power Import Power Lagging VArs Leading VArs	– + – +

Table 9 – Measurement mode options

In addition to the measured power quantities the relay calculates the power factor on a phase by phase basis in addition to a three-phase power factor.

These power values are also used to increment the total real and reactive energy measurements. Separate energy measurements are maintained for the total exported and imported energy. The energy measurements are incremented up to maximum values of 1000 GWhr or 1000 GVARhr at which point they will reset to zero, it is also possible to reset these values using the menu or remote interfaces using the reset demand cell.

4.5 Rms. Voltages and Currents

Rms. phase voltage and current values are calculated by the relay using the sum of the samples squared over a cycle of sampled data.

4.6 Demand Values

The relay produces fixed, rolling and peak demand values, using the reset demand menu cell it is possible to reset these quantities via the user interface or the remote communications.

Fixed Demand Values

The fixed demand value is the average value of a quantity over the specified interval; values are produced for each phase current and for three phase real and reactive power. The fixed demand values displayed by the relay are those for the previous interval, the values are updated at the end of the fixed demand period.

Rolling Demand Values

The rolling demand values are similar to the fixed demand values, the difference being that a sliding window is used. The rolling demand window consists of a number of smaller sub-periods. The resolution of the sliding window is the sub-period length, with the displayed values being updated at the end of each of the sub-periods.

Peak Demand Values

Peak demand values are produced for each phase current and the real and reactive power quantities. These display the maximum value of the measured quantity since the last reset of the demand values.

4.7 Settings

The following settings under the heading measurement set-up can be used to configure the relay measurement function.

Menu Text	Default Settings	Available settings
MEASUREMENT SETUP		
Default Display	Description	Description/Plant Reference/ Frequency/Access Level/3Ph + N Current/3Ph Voltage/Power/Date and Time
This setting can be used to select the default display from a range of options, Note *It is also possible to view the other default displays whilst at the default level using the ◁ and ▷ keys. However once the 15 minute timeout elapses the default display will revert to that selected by this setting.*		
Local Values	Primary	Primary/Secondary
This setting controls whether measured values via the front panel user interface and the front courier port are displayed as primary or secondary quantities.		
Remote Values	Primary	Primary/Secondary
This setting controls whether measured values via the rear communication port are displayed as primary or secondary quantities.		
Measurement Ref.	VA	VA/VB/VC/IA/IB/IC
Using this setting the phase reference for all angular measurements by the relay can be selected.		
Measurement Mode	0	0 to 3 step 1
This setting is used to control the signing of the real and reactive power quantities; the signing convention used is defined in section 4.4		
Fix Dem. Period	30 minutes	1 to 99 minutes step 1 minute
This setting defines the length of the fixed demand window.		
Roll Sub Period	30 minutes	1 to 99 minutes step 1 minute
These two settings are used to set the length of the window used for the calculation of rolling demand quantities.		
Num. Sub Periods	1	1 to 15 step 1
This setting is used to set the resolution of the rolling sub window.		
Distance Unit*	km	km/miles
This setting is used to select the unit of distance for fault location purposes, Note: The length of the line is preserved when converting from km to miles and vice versa.		
Fault Location*	Distance	Distance/Ohms/% of Line
The calculated fault location can be displayed using one of several options selected using this setting.		
Remote2 Values	Primary	Primary or Secondary
The setting defines whether the values measured via the 2nd Rear Communication port are displayed in primary or secondary terms.		

Table 10 – Measurement setup

4.8 Measurement Display Quantities

There are three “Measurement” columns available in the relay for viewing of measurement quantities. These can also be viewed with MiCOM S1 (see MiCOM Px40 - Monitoring section of the MiCOM S1 Studio User Manual) and are shown in Table 11:

MEASUREMENTS 1		MEASUREMENTS 2		MEASUREMENTS 4	
IA Magnitude	0 A	A Phase Watts	0 W	Ch 1 Prop Delay	
IA Phase Angle	0 deg	B Phase Watts	0 W	Ch 2 Prop Delay	
IB Magnitude	0 A	C Phase Watts	0 W	Channel 1 Status	
IB Phase Angle	0 deg	A Phase VArs	0 Var	Channel 2 Status	
IC Magnitude	0 A	B Phase VArs	0 Var	IM64 Rx Status	
IC Phase Angle	0 deg	C Phase VArs	0 Var	STATISTICS	
IN Derived Mag.	0 A	A Phase VA	0 VA	Last Reset on	
IN Derived Angle	0 deg	B Phase VA	0 VA	Date/Time	
ISEF Magnitude	0 A	C Phase VA	0 VA	Ch1 No.Vald Mess	
ISEF Angle	0 deg	3 Phase Watts	0 W	Ch1 No.Err Mess	
I1 Magnitude	0 A	3 Phase VArs	0 VAr	Ch1 No.Errored s	
I2 Magnitude	0 A	3 Phase VA	0 VA	Ch1 No.Sev Err s	
I0 Magnitude	0 A	3Ph Power Factor	0	Ch1 No.Dgraded m	
IA RMS	0 A	APh Power Factor	0	Ch2 No.Vald Mess	
IB RMS	0 A	BPh Power Factor	0	Ch2 No.Err Mess	
IC RMS	0 A	CPh Power Factor	0	Ch2 No.Errored s	
IN RMS	0 A	3Ph WHours Fwd	0 Wh	Ch2 No.Sev Err s	
VAB Magnitude	0 V	3Ph WHours Rev	0 Wh	Ch2 No.Dgraded m	
VAB Phase Angle	0 deg	3Ph VArHours Fwd	0 VArh	Max Ch 1 Prop Delay	
VBC Magnitude	0 V	3Ph VArHours Rev	0 VArh	Max Ch 2 Prop Delay	
VBC Phase Angle	0 deg	3Ph W Fix Demand	0 W	Clear Statistics	
VCA Magnitude	0 V	3Ph VArs Fix Dem.	0 VAr		
VCA Phase Angle	0 deg	IA Fixed Demand	0 A		
VAN Magnitude	0 V	IB Fixed Demand	0 A		
VAN Phase Angle	0 deg	IC Fixed Demand	0 A		
VBN Magnitude	0 V	3 Ph W Roll Dem.	0 W		
VBN Phase Angle	0 deg	3Ph VArs Roll Dem.	0 VAr		
VCN Magnitude	0 V	IA Roll Demand	0 A		
VCN Phase Angle	0 deg	IB Roll Demand	0 A		
		IC Roll Demand	0 A		
		3Ph W Peak Dem.	0 W		
V1 Magnitude	0 V	3Ph VAr Peak Dem.	0 VAr		
V2 Magnitude	0 V	IA Peak Demand	0 A		
V0 Magnitude	0 V	IB Peak Demand	0 A		
VAN RMS	0 V	IC Peak Demand	0 A		
VBN RMS	0 V	Reset Demand	No		
VCN RMS	0 V				
VAB RMS	0 V				
VBC RMS	0 V				
VCA RMS	0 V				
Frequency					
CB1 CS Volt Mag	0 V				
CB1 CS Volt Ang	0 deg				

MEASUREMENTS 1		MEASUREMENTS 2		MEASUREMENTS 4	
CB1 Bus-Line Ang	0 deg				
CB1 CS Slip Freq					
IM Magnitude	0 A				
IM Phase Angle	0 deg				
I1 Magnitude	0 A				
I1 Phase Angle	0 deg				
I2 Magnitude	0 A				
I2 Phase Angle	0 deg				
I0 Magnitude	0 A				
I0 Phase Angle	0 deg				
V1 Magnitude	0 V				
V1 Phase Angle	0 deg				
V2 Magnitude	0 V				
V2 Phase Angle	0 deg				
V0 Magnitude	0 V				
V0 Phase Angle	0 deg				
CB2 CS Volt Mag	0 V				
CB2 CS Volt Ang	0 deg				
CB2 Bus-Line Ang	0 deg				
CB2 CS Slip Freq					
VRem Magnitude	0 V				
VRem Phase Ang	0 deg				
P446 only					
IA CT1 Magnitude	0 A				
IA CT1 Phase Ang	0 deg				
IB CT1 Magnitude	0 A				
IB CT1 Phase Ang	0 deg				
IC CT1 Magnitude	0 A				
IC CT1 Phase Ang	0 deg				
IA CT2 Magnitude	0 A				
IA CT2 Phase Ang	0 deg				
IB CT2 Magnitude	0 A				
IB CT2 Phase Ang	0 deg				
IC CT2 Magnitude	0 A				
IC CT2 Phase Ang	0 deg				

Table 11 - Measurements

4.8.1 Measurements 4 Column

The contents of the Measurements 4 column are associated with the InterMiCOM64 feature. Two InterMiCOM^{64} channels can be supported referred to as Channel1 (Ch1) and Channel2 (Ch2)

Channel 1 and Channel 2 propagation times are displayed in seconds. The time represents the time from the start of transmission of an InterMiCOM^{64} message to the completion of its reception by the remote device.

'Channel Status 1' is a diagnostics flag associated with each channel. The bits associated with the Channel 1 condition are described below (Channel 2 is similar).

• Bit "Max Prop Delay"	If the "Prop Delay Stats" is enabled, this bit indicates that the propagation delay time is above the setting.

Bit “Passthrough”	This indicates that, in a three-terminal configuration, Ch1 data has been received on Ch2 via the self healing ring mechanism.
Bit “Message Level”	Is indicative of the quality of the signal on Channel 1
Bit “Timeout”	Indication that no valid messages are received over Channel 1 during the ‘Channel Timeout’ window
Bit “Mismatch Rxn”	Indication of mismatch between the InterMiCOM^{64} Ch1 setting and that of the associated multiplexer
Bit “Path Yellow”	An indication of one way communication. The local relay is being informed by the remote connected relay that the remote connected relay is not receiving messages from the local one
Bit “Signal Lost”	An indication from the associated multiplexer that Channel1 signals are being lost
Bit “Mux Clk F Error”	This is an alarm that appears if the Channel 1 baud rate is outside the limits 52 Kbis/s or 70 Kbits/s
Bit “Tx”	Indication of transmission on Channel 1
Bit “Rx”	Indication of reception on Channel 1

‘IM64 Rx Status’ is a 16 bit word that displays the status of received commands as “1” or “0”.

‘Last Reset on’ displays the time and date of last statistics reset.

‘Ch1/Ch2 No. of valid messages’ displays the number of received valid messages over channel 1/2 since last statistics reset.

‘Ch1/Ch2 No. of Errored messages’ displays the number of invalid messages over channel 1/Ch 2 since last statistics reset.

The number of errored messages complies with ITU- G8.21 and is as follows:

‘Ch1/Ch2 No. Errored seconds’ displays the number of seconds containing 1 or more errored or lost messages

‘Ch1/Ch2 No. Severely Errored seconds‘ displays the number of seconds containing 31 or more errored or lost messages (see Note 1).

Note 1 *Any severely errored seconds are ignored when working out the minutes intervals*

‘Ch1/Ch2 No. Degraded minutes’ displays the number of minutes containing 2 or more errored or lost messages.

The number of lost messages recorded is intended as an indicator for noises under normal communication conditions and not for recording long communication breaks. The lost message count is accumulated by incrementing a counter when a message is rejected by the Error code check, message length check and the sequential time tag check.

‘Max Ch 1/2 Prop Delay’ displays the maximum value of the overall propagation delay divided by 2 when the protection communications are enabled.

The error statistics are automatically cleared on power-up. They can also be cleared using the Clear Statistics setting in Measurements column of the menu.

Note *MEASUREMENT 3 column is intentionally blank (reserved for future use)*

Notes:

FIRMWARE DESIGN

CHAPTER 9

Date:	12/2012
Hardware Suffix:	K (P443, P446, P543, P544, P545, P546, P547, P643 & P645) and J (P445 & P642)
Software Version:	35/36 (P445) 45 (P543/P544/P545/P546 without Distance) 55 (P443/P446/P543/P544/P545/P546 with Distance) 57 (P547) 04 (P642/P643 & P645)
Connection Diagrams:	10P44303 (SH 01 and 03) 10P44304 (SH 01 and 03) 10P44305 (SH 01 and 03) 10P44306 (SH 01 and 03)
	10P445xx (xx = 01 to 04)
	10P44600 10P44601 (SH 1 to 2) 10P44602 (SH 1 to 2) 10P44603 (SH 1 to 2)
	10P54302 (SH 1 to 2) 10P54303 (SH 1 to 2)
	10P54400 10P54404 (SH 1 to 2) 10P54405 (SH 1 to 2)
	10P54502 (SH 1 to 2) 10P54503 (SH 1 to 2)
	10P54600 10P54604 (SH 1 to 2) 10P54605 (SH 1 to 2) 10P54606 (SH 1 to 2)
	10P54702xx (xx = 01 to 02) 10P54703xx (xx = 01 to 02) 10P54704xx (xx = 01 to 02) 10P54705xx (xx = 01 to 02)
	10P642xx (xx = 01 to 10) 10P643xx (xx = 01 to 06) 10P645xx (xx = 01 to 09)

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Notes:

1 RELAY SYSTEM OVERVIEW

1.1 Hardware Overview

The relay hardware is based on a modular design. The different modules that can be present in the relay are as follows:

1.1.1 Processor Board

The processor board performs all calculations for the relay and controls the operation of all other modules within the relay. The processor board also contains and controls the user interfaces (LCD, LEDs, keypad, function keys and communication interfaces).

1.1.2 Co-Processor Board (optionally with InterMiCOM^{64} Fiber Teleprotection)

This section does not apply to the P64x (P642, P643 or P645) products.

Used to process the distance protection and delta directional algorithms. It contains the optical fiber transmit and receive hardware and serial data communication controller for the InterMiCOM^{64} teleprotection. InterMiCOM^{64} is an extra cost ordering option.

1.1.3 Analog/Digital Input Module

The input module converts the information contained in the analog and digital input signals into a format suitable for processing by the processor board. The input module consists of two boards: a transformer board to provide electrical isolation and a main input board which provides analog to digital conversion (with local storage of the calibration data) and the isolated digital (“**opto**”) inputs.

P446	*The input module for a P446 contains an additional transformer board to accommodate the additional analog inputs demanded by the application.*

1.1.4 Power Supply Module

The power supply module provides a power supply to all of the other modules in the relay, at three different voltage levels. The power supply board also provides the EIA(RS)485 electrical connection for the rear communication port. On a second board the power supply module contains the relays that provide the output contacts.

The power supply module also provides a 48V external field supply output to drive the opto isolated digital inputs (or the substation battery may be used to drive the optos).

1.1.5 IRIG-B Modulated or Un-modulated Board (Optional)

This board, can be used where an IRIG-B signal is available to provide an accurate time reference for the relay. There is also an option on this board to specify a fiber optic rear communication port, for use with IEC 60870 communications only.

1.1.6 Second Rear Comms and EIA(RS)232 InterMiCOM^{64} Board (Optional)

The optional second rear port is designed typically for dial-up modem access by protection engineers/operators, when the main port is reserved for SCADA traffic. Communication is via one of three physical links: K-Bus, EIA(RS)485 or EIA(RS)232. The port supports full local or remote protection and control access by MiCOM S1 software. The second rear port is also available with an on board IRIG-B input.

The optional board also houses port “SK5”, the EIA232 InterMiCOM teleprotection port. InterMiCOM permits end-to-end signaling with a remote MiCOM relay, for example in a distance protection channel aided scheme. Port SK5 has an EIA(RS)232 connection, allowing connection to a MODEM, or compatible multiplexers.

1.1.7 Ethernet Board

This board provides the Ethernet connectivity for protocols support on that Media. It provides network connectivity through either copper or fiber media at rates of 10Mb/s (copper only) or 100Mb/s. There is also an option on this board to specify IRIG-B port (modulated or un-modulated). This board, the IRIG-B board mentioned in section 1.1.5 and second rear comms board mentioned in section 1.1.6 are mutually exclusive as they all use slot A within the relay case.

All modules are connected by a parallel data and address bus which allows the processor board to send and receive information to and from the other modules as required. There is also a separate serial data bus for conveying sample data from the input module to the processor. Figure 1 shows the modules of the relay and the flow of information between them.

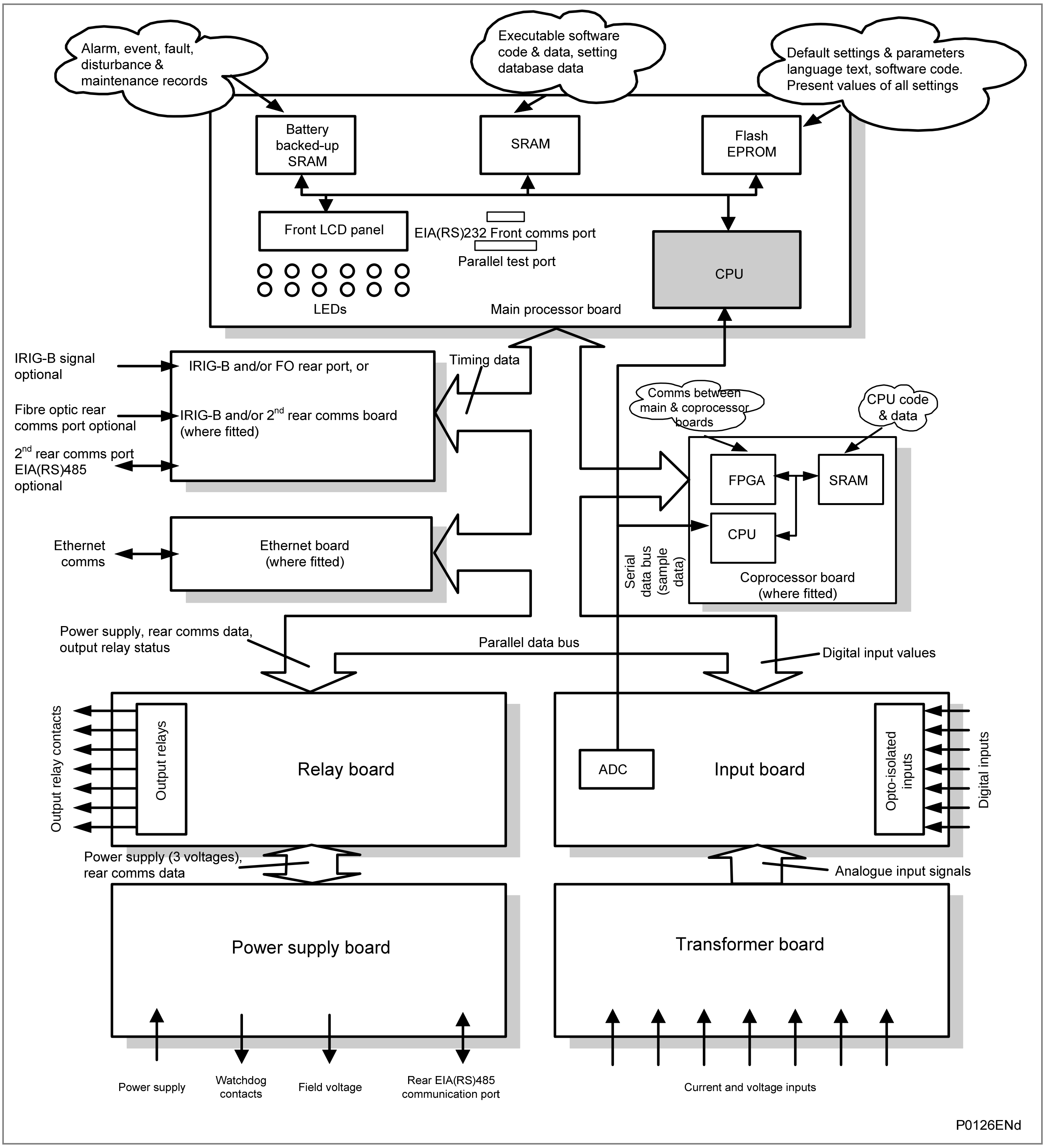

Alarm, event, fault, disturbance & maintenance records
Executable software code & data, setting database data
Default settings & parameters language text, software code. Present values of all settings
Battery backed-up SRAM
SRAM
Flash EPROM
Front LCD panel
EIA(RS)232 Front comms port
Parallel test port
CPU
LEDs
Main processor board
IRIG-B signal optional
Fibre optic rear comms port optional
2nd rear comms port EIA(RS)485 optional
IRIG-B and/or FO rear port, or
IRIG-B and/or 2nd rear comms board (where fitted)
Timing data
Comms between main & coprocessor boards
CPU code & data
FPGA
SRAM
CPU
Coprocessor board (where fitted)
Serial data bus (sample data)
Ethernet comms
Ethernet board (where fitted)
Power supply, rear comms data, output relay status
Parallel data bus
Digital input values
Output relay contacts
Output relays
Relay board
ADC
Input board
Opto-isolated inputs
Digital inputs
Power supply (3 voltages), rear comms data
Analogue input signals
Power supply board
Transformer board
Power supply
Watchdog contacts
Field voltage
Rear EIA(RS)485 communication port
Current and voltage inputs
P0126ENd

Figure 1 - Relay modules and information flow

1.2 Software Overview

The software for the relay can be conceptually split into four elements; the real-time operating system, the system services software, the platform software and the protection and control software. These four elements are not distinguishable to the user, and are all processed by the same processor board. The distinction between the four parts of the software is made purely for the purpose of explanation here.

1.2.1 Real-Time Operating System

The real time operating system is used to provide a framework for the different parts of the relay's software to operate within. To this end the software is split into tasks.

The real-time operating system is responsible for scheduling the processing of these tasks such that they are carried out in the time available and in the desired order of priority. The operating system is also responsible for the exchange of information between tasks, in the form of messages.

1.2.2 System Services Software

The system services software provides the low-level control of the relay hardware. For example, the system services software controls the boot of the relay's software from the non-volatile flash EPROM memory at power-on, and provides driver software for the user interface via the LCD and keypad, and via the serial communication ports. The system services software provides an interface layer between the control of the relay's hardware and the rest of the relay software.

1.2.3 Platform Software

The platform software deals with the management of the relay settings, the user interfaces and logging of event, alarm, fault and maintenance records. All of the relay settings are stored in a database within the relay which provides direct compatibility with Courier communications. For all other interfaces (i.e. the front panel keypad and LCD interface, IEC 60870-5-103, DNP3.0 and IEC 61850) the platform software converts the information from the database into the format required. The platform software notifies the protection and control software of all settings changes and logs data as specified by the protection and control software.

The P64x (P642, P643 or P645) products include the MODBUS interface but excludes the IEC61850 interface.

1.2.4 Protection and Control Software

The protection and control software performs the calculations for all of the protection algorithms of the relay. This includes digital signal processing, filtering, and ancillary tasks such as the measurements. The protection and control software interfaces with the platform software for settings changes and logging of records, and with the system services software for acquisition of sample data and access to output relays and digital opto-isolated inputs.

1.2.5 Disturbance Recorder

The analog values and logic signals are routed from the protection and control software to the disturbance recorder software. The platform software interfaces to the disturbance recorder to allow extraction of the stored records.

2 HARDWARE MODULES

The relay is based on a modular hardware design where each module performs a separate function within the relay operation. This section describes the functional operation of the various hardware modules.

2.1 Processor Board

The relay is based around a TMS320VC33-150MHz (peak speed), floating-point, 32-bit Digital Signal Processor (DSP) operating at a clock frequency of half this speed. This processor performs all of the calculations for the relay, including the protection functions, control of the data communication and user interfaces including the operation of the LCD, keypad and LEDs.

The processor board is located directly behind the relay’s front panel which allows the LCD and LEDs to be mounted on the processor board along with the front panel communication ports. These comprise the 9-pin D-connector for EIA(RS)232 serial communications (e.g. using MiCOM S1 Studio and Courier communications) and the 25-pin D-connector relay test port for parallel communication. All serial communication is handled using a Field Programmable Gate Array (FPGA).

The memory provided on the main processor board is split into two categories, volatile and non-volatile: the volatile memory is fast access SRAM which is used for the storage and execution of the processor software, and data storage as required during the processor’s calculations. The non-volatile memory is sub-divided into 2 groups: 4MB of flash memory for non-volatile storage of software code, text and configuration data including the present setting values, and 2MB (see note) of battery backed-up SRAM for the storage of disturbance, event, fault and maintenance record data.

Note *The P64x (P642, P643 or P645) product has 4MB of battery-backed RAM.*

2.2 Co-Processor Board (not in the P64x -P642/P643/P645 product)

A second processor board is used in the relay for the processing of the distance and delta protection algorithms. The processor used on the second board is the same as that used on the main processor board. The second processor board has provision for fast access (zero wait state) SRAM for use with both program and data memory storage. This memory can be accessed by the main processor board via the parallel bus, and this route is used at power-on to download the software for the second processor from the flash memory on the main processor board. Further communication between the two processor boards is achieved via interrupts and the shared SRAM. The serial bus carrying the sample data is also connected to the co-processor board, using the processor’s built-in serial port, as on the main processor board.

The co-processor board also handles any communication with the remote differential relay(s). This is achieved via BFOC 2.5 - ST optical fiber connections at the rear and hence the co-processor board holds the optical modules to transmit and receive data over the fiber links. One or two channels will be provided, each comprising a Rx (receive) and a Tx (transmit) fiber as a pair. The channels, when fitted according to an ordering option, are labeled Ch1 and Ch2.

2.3 Internal Communication Buses

The relay has two internal buses for the communication of data between different modules. The main bus is a parallel link that is part of a 64-way ribbon cable. The ribbon cable carries the data and address bus signals in addition to control signals and all power supply lines. Operation of the bus is driven by the main processor board that operates as a master while all other modules within the relay are slaves.

The second bus is a serial link that is used exclusively for communicating the digital sample values from the input module to the main processor board. The DSP processor has a built-in serial port that is used to read the sample data from the serial bus. The serial bus is also carried on the 64-way ribbon cable.

2.4 Input Module

The input module provides the interface between the relay processor board and the analog and digital signals coming into the relay. The input module has these features:

Relay	PCBs			Inputs	
	No of PCBs	No of Main Input Boards	No of Transformer Boards	Voltage	Current
P443	2	1	1	4	5
P445	2	1	1	4	4
P446	3	1	2	5	8
P543	2	1	1	4	5
P544	3	1	2	5	8
P545	2	1	1	4	5
P546	3	1	2	5	8
P547	2	1	1	4	5
P642	2	1	1	1 or 2	8
P643	2	1	1	2	3 or 9
P645	2	1	1	2	9

Table 1 - PCBs and voltage/current inputs for different relay types

2.4.1 Transformer Board

The current inputs will accept either 1A or 5A nominal current (observe menu and wiring options) and the nominal voltage input is 100/110/115/120V.

The transformers are used both to step-down the currents and voltages to levels appropriate to the relay's electronic circuitry and to provide effective isolation between the relay and the power system. The connection arrangements of both the current and voltage transformer secondary's provide differential input signals to the main input board to reduce noise.

2.4.2 Input Board

The main input board is shown in Figure 2 (P443 version) and Figure 3 (P445 version) , Figure 4 (P54x/P547 version) or Figure 5 (P64x - P642/P643/P645 version).

It provides the circuitry for the digital input signals and the analog-to-digital conversion for the analog signals. Hence it takes the differential analog signals from the CTs and VTs on the transformer board(s), converts these to digital samples and transmits the samples to the processor board via the serial data bus. On the input board the analog signals are passed through an anti-alias filter before being multiplexed into a single analog to digital converter chip. The A - D converter provides 16-bit resolution and a serial data stream output. The digital input signals are opto isolated on this board to prevent excessive voltages on these inputs causing damage to the relay's internal circuitry.

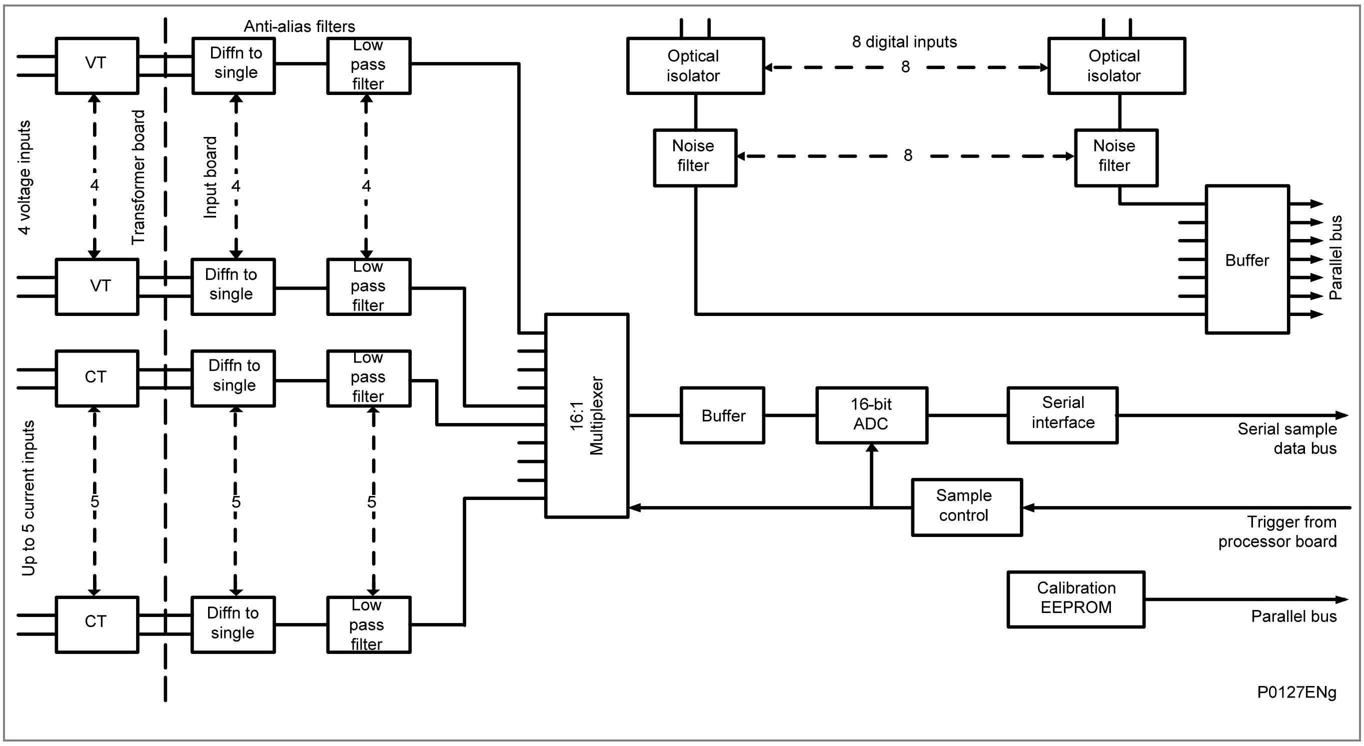

Anti-alias filters
VT
Diffn to single
Low pass filter
4 voltage inputs
Transformer board
Input board
4
VT
CT
Up to 5 current inputs
5
CT
16:1 Multiplexer
Optical isolator
8 digital inputs
8
Noise filter
Buffer
Parallel bus
16-bit ADC
Serial interface
Serial sample data bus
Sample control
Trigger from processor board
Calibration EEPROM
Parallel bus
P0127ENg

Figure 2 - Main input board for P443

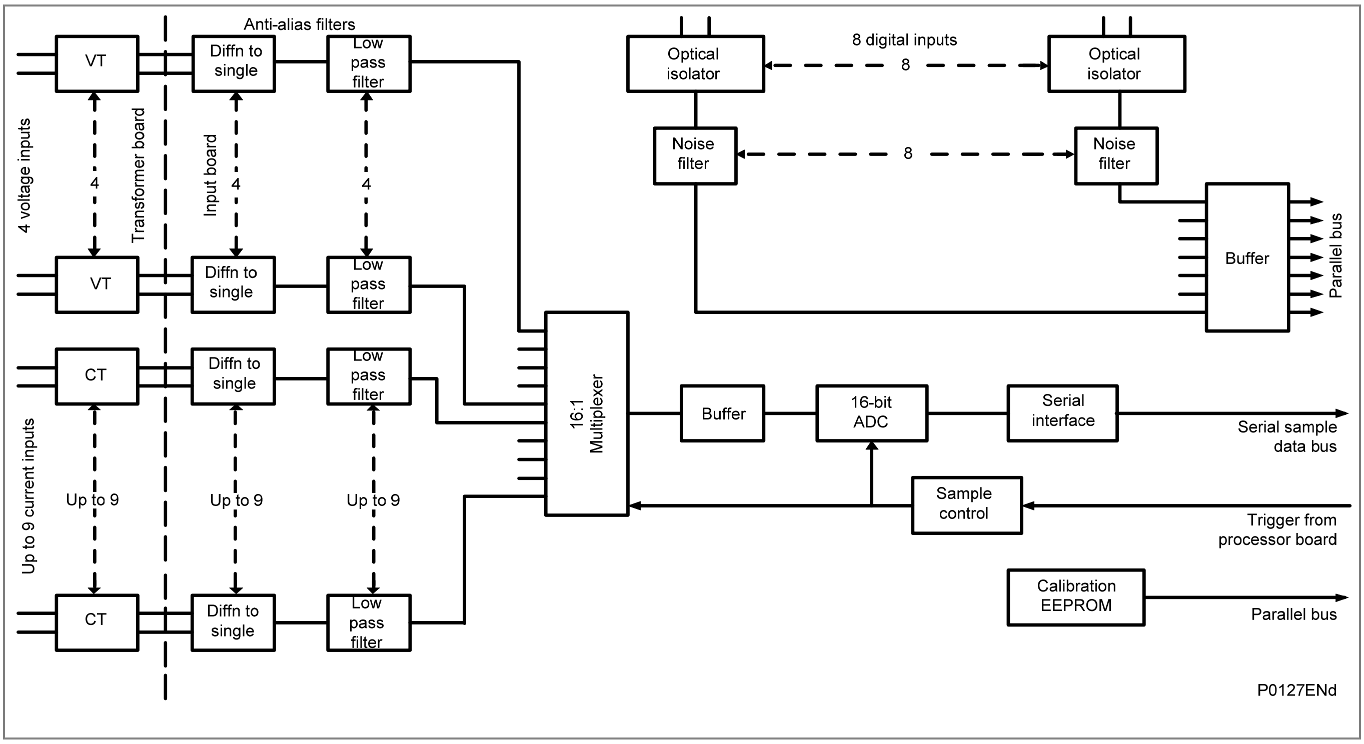

Anti-alias filters
VT
Diffn to single
Low pass filter
4 voltage inputs
Transformer board
Input board
4
VT
CT
Up to 9 current inputs
Up to 9
CT
16:1 Multiplexer
Optical isolator
8 digital inputs
8
Noise filter
Buffer
Parallel bus
16-bit ADC
Serial interface
Serial sample data bus
Sample control
Trigger from processor board
Calibration EEPROM
Parallel bus
P0127ENd

Figure 3 - Main input board for P445

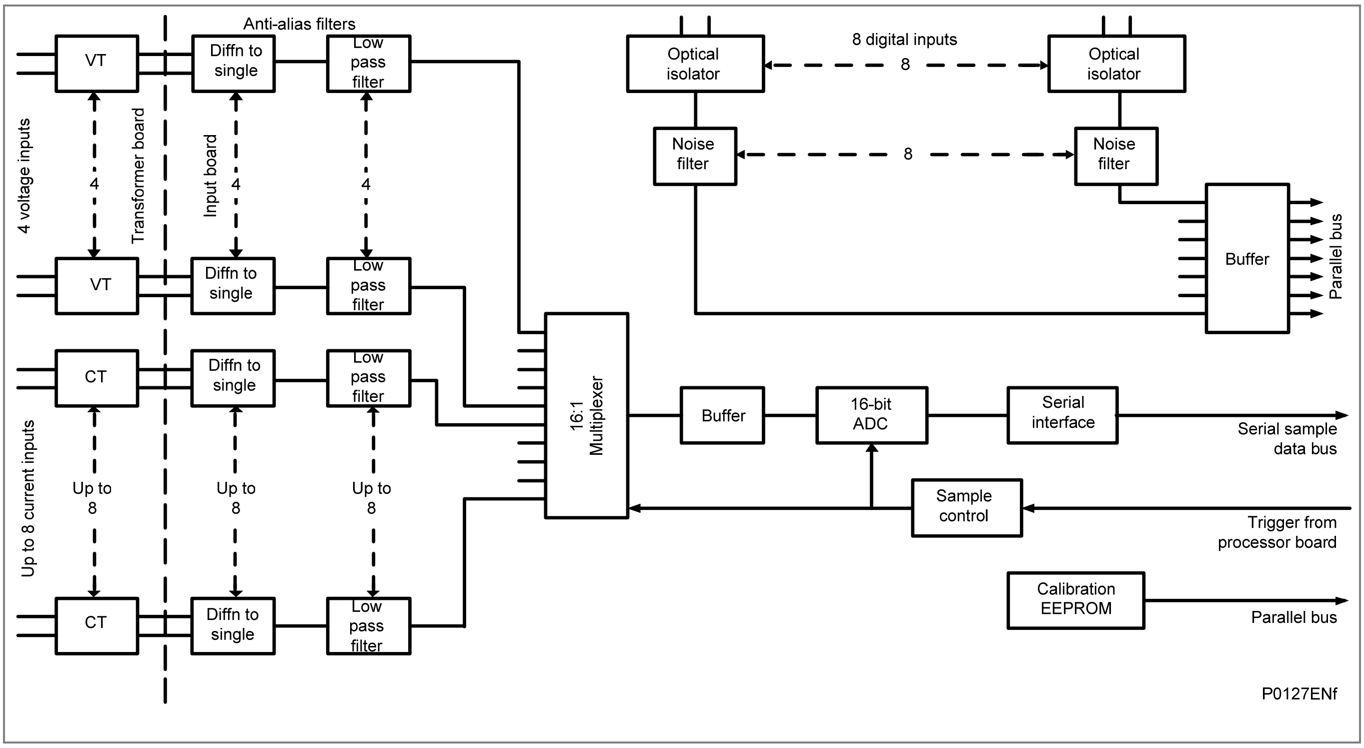

Anti-alias filters
VT
Diffn to single
Low pass filter
4 voltage inputs
Transformer board
Input board
4
4
4
VT
Diffn to single
Low pass filter
CT
Diffn to single
Low pass filter
Up to 8 current inputs
Up to 8
Up to 8
Up to 8
CT
Diffn to single
Low pass filter
16:1 Multiplexer
Optical isolator
8 digital inputs
8
Optical isolator
Noise filter
8
Noise filter
Buffer
Parallel bus
Buffer
16-bit ADC
Serial interface
Serial sample data bus
Sample control
Trigger from processor board
Calibration EEPROM
Parallel bus
P0127ENf

Figure 4 - Main input board for P54x (P543/P544/P545/P546) and P547

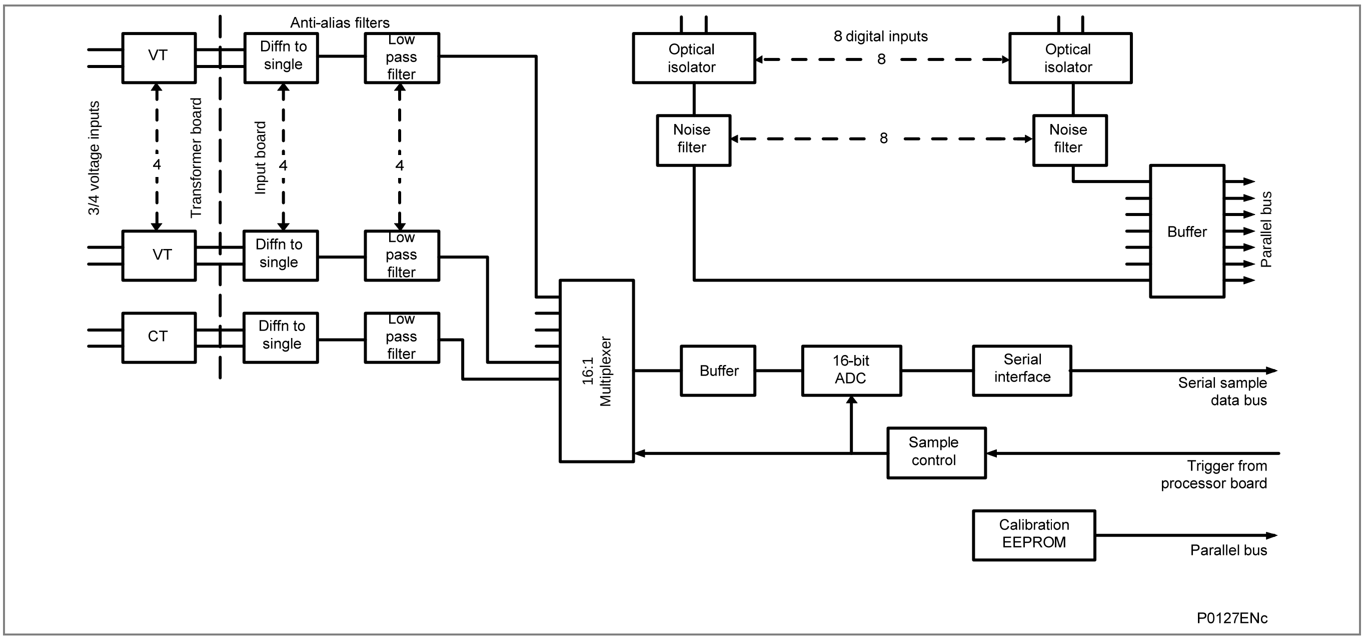

Anti-alias filters
VT
Diffn to single
Low pass filter
3/4 voltage inputs
Transformer board
Input board
4
4
4
VT
Diffn to single
Low pass filter
CT
Diffn to single
Low pass filter
16:1 Multiplexer
Optical isolator
8 digital inputs
8
Optical isolator
Noise filter
8
Noise filter
Buffer
Parallel bus
Buffer
16-bit ADC
Serial interface
Serial sample data bus
Sample control
Trigger from processor board
Calibration EEPROM
Parallel bus
P0127ENc

Figure 5 - Main input board for P64x (P642/P643/P645)

Three spare channels are used to sample three different reference voltages for the purpose of continually checking the operation of the multiplexer and the accuracy of the A-D converter. The sample rate is maintained at 48 samples per cycle (see note) of the power waveform by a logic control circuit which is driven by the frequency tracking function on the main processor board.

Note *24 samples per cycle for the P64x (P643, P643 & P645) products.*

The calibration non-volatile memory holds the calibration coefficients which are used by the processor board to correct for any amplitude or phase errors introduced by the transformers and analog circuitry.

The other function of the input board is to read the state of the signals present on the digital inputs and present this to the parallel data bus for processing. The input board holds eight optical isolators for the connection of up to eight digital input signals. The opto-isolators are used with the digital signals for the same reason as the transformers with the analog signals; to isolate the relay's electronics from the power system environment. The input board provides some hardware filtering of the digital signals to remove unwanted noise before buffering the signals for reading on the parallel data bus.

Depending on the relay model, more than eight digital input signals can be accepted by the relay. This is achieved by the use of an additional opto-board which contains the same provision for eight isolated digital inputs as the main input board, but does not contain any of the circuits for analogue signals which are provided on the main input board.

2.4.3 Universal Opto Isolated Logic Inputs

The relay is fitted with universal opto isolated logic inputs that can be programmed for the nominal battery voltage of the circuit of which they are a part i.e. thereby allowing different voltages for different circuits e.g. signaling, tripping. They can also be programmed as Standard 60% - 80% or 50% - 70% to satisfy different operating constraints. The threshold levels are shown in Table 2:

Nominal Battery Voltage (Vdc)	Standard 60% - 80%		50% - 70%	
	No Operation (logic 0) Vdc	Operation (logic 1) Vdc	No Operation (logic 0) Vdc	Operation (logic 1) Vdc
24/27	<16.2	>19.2	<12.0	>16.8
30/34	<20.4	>24.0	<15.0	>21.0
48/54	<32.4	>38.4	<24.0	>33.6
110/125	<75.0	>88.0	<55.0	>77.0
220/250	<150.0	>176.0	<110.0	>154.0

Table 2 - Threshold levels

This lower value eliminates fleeting pickups that may occur during a battery earth fault, when stray capacitance may present up to 50% of battery voltage across an input.

Each input also has selectable filtering which can be used. This allows use of a pre-set filter of ½ cycle which renders the input immune to induced noise on the wiring: although this method is secure it can be slow, particularly for intertripping. This can be improved by switching off the ½ cycle filter in which case one of the following methods to reduce ac noise should be considered. The first method is to use double pole switching on the input, the second is to use screened twisted cable on the input circuit.

Relay Model	No of Opto Inputs	Notes
P443 models A and C	16	
P443 models B and D	24	
P445 model A	8	
P445 model B	12	Achieved by using a special combined input output board which has 4 inputs and 4 outputs
P445 models C or D	16	Achieved by fitting an additional, part-populated input board
P446	24	
P543	16	

Relay Model	No of Opto Inputs	Notes
P544	16	
P545	24	Or 32 by certain ordering options
P546	24	
P547 80TE	16 and 24	
P642	8	12 with certain ordering options
P643	16	24 with certain ordering options
P645	16	24 with certain ordering options

Table 3 - Numbers of opto inputs for different models

2.5 Power Supply Module (including Output Relays)

The power supply module contains two PCBs, one for the power supply unit itself and the other for the output relays. The power supply board also contains the input and output hardware for the rear communication port which provides an EIA(RS)485 communication interface.

2.5.1 Power Supply Board (including EIA(RS)485 Communication Interface)

One of three different configurations of the power supply board can be fitted to the relay. This will be specified at the time of order and depends on the nature of the supply voltage that will be connected to the relay. The three options are shown in Table 4:

Nominal dc Range	Nominal ac Range
24/48 V	DC only
48/110 V	40/100 Vrms
110/250 V	100/240 Vrms

Table 4 - Nominal ac and dc ranges

The output from all versions of the power supply module are used to provide isolated power supply rails to all of the other modules within the relay. Three voltage levels are used within the relay, 5.1V for all of the digital circuits, ±16V for the analogue electronics, e.g. on the input board, and 22V for driving the output relay coils. All power supply voltages including the 0V earth line are distributed around the relay via the 64-way ribbon cable. One further voltage level is provided by the power supply board which is the field voltage of 48V. This is brought out to terminals on the back of the relay so that it can be used to drive the optically isolated digital inputs.

The two other functions provided by the power supply board are the EIA(RS)485 communications interface and the watchdog contacts for the relay. The EIA(RS)485 interface is used with the relay’s rear communication port to provide communication using one of either Courier, IEC 60870-5-103 or DNP3.0 protocols (see note). The EIA(RS)485 hardware supports half-duplex communication and provides optical isolation of the serial data being transmitted and received. All internal communication of data from the power supply board is conducted via the output relay board which is connected to the parallel bus.

Note *P64x (P642, P643 & P645) products can use the MODBUS protocol too.*

The watchdog facility provides two output relay contacts, one normally open and one normally closed which are driven by the processor board. These are provided to give an indication that the relay is in a healthy state.

The power supply board incorporates inrush current limiting. This limits the peak inrush current, during energization, to approximately 10A.

2.5.2 Output Relay Board

The standard output relay boards hold different numbers of relays with normally open contacts and with changeover contacts. The relevant numbers are as follows:

Relay Model	No of Relay Contacts	No of normally open contacts	No of changeover contacts
P443/P445/P446	8	6	2
P543/P544	7	3	4
P545/P546/P547	8	6	2

Relay Model	No of Relay Contacts	No of normally open contacts	No of changeover contacts
P642/P643/P645	8	6	2

Table 5 - Numbers of relay contacts for different models

The relays are driven from the 22 V power supply line. The relays' state is written to or read from using the parallel data bus. Depending on the relay model up to 32 output contacts may be provided through the use of up to 4 standard output relay boards.

2.5.3 High Break Relay Board

One 'high break' output relay board consists of four normally open output contacts. Arrangements of those boards are as follows:

Relay Model	No of high break output relay boards	Total standard relay outputs	Total high break relay outputs
P443 model C	1	16	4
P443 model D	2	16	8
P445 models A, B and C	0		
P445 model D	1	8	4
P446 model B	3	8	12
P446 model C	2	16	8
P543/P544	1 (to replace a standard board)	7	4
P545	2 (to replace standard boards)	16	8
P546 with option A	2 (to replace standard boards)	16	8
P546 with option B	3 (to replace standard boards)	8	12
P547 80TE	2	16	8
P642 (optional)	1	8	4
P643/P645 (optional)	2	16	8

Table 6 - Numbers of relay contacts for different models

Note	*These relay contacts are POLARITY SENSITIVE. External wiring must comply with the polarity requirements described in the external connection diagram to ensure correct operation.*

This board contains a hybrid of MOSFET Solid State Devices (SSD) in parallel with high capacity relay output contacts. The MOSFET has a varistor across it to provide protection which is required when switching off inductive loads as the stored energy in the inductor causes a reverse high voltage which could damage the MOSFET.

When there is a control input command to operate an output contact the miniature relay is operated at the same time as the SSD. The miniature relay contact closes in nominally 3.5mS and is used to carry the continuous load current; the SSD operates in <0.2ms and is switched off after 7.5mS. When the control input resets to open the contacts, the SSD is again turned on for 7.5mS. The miniature relay resets in nominally 3.5ms before the SSD and so the SSD is used to break the load. The SSD absorbs the energy when breaking inductive loads and so limits the resulting voltage surge. This contact arrangement is for switching dc circuits only. As the SSD comes on very fast (<0.2ms) then these high break output contacts have the added advantage of being very fast operating.

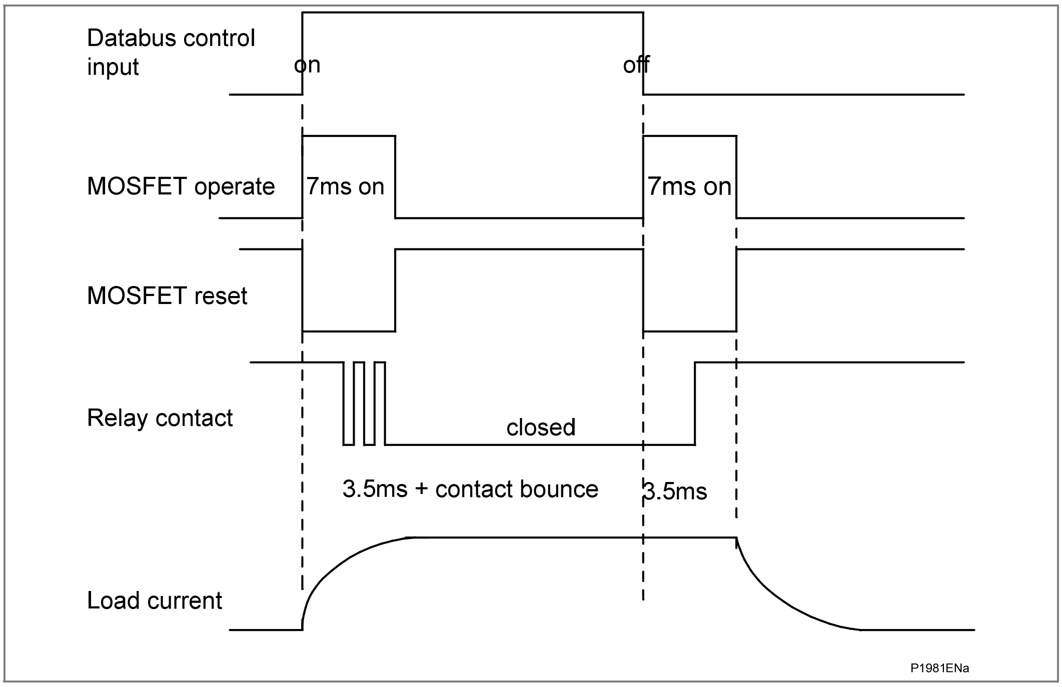


Figure 6 - High break contact operation

2.5.4 High Break Contact Applications

1. Efficient Scheme Engineering

   In traditional hardwired scheme designs, high break capability could only be achieved using external electromechanical trip relays. External MVAJ tripping relays can be used or the new high break contacts inside MiCOM relays can be used - reducing panel space.

2. Accessibility of CB Auxiliary Contacts

   Common practice is to use circuit breaker 52a (CB Closed) auxiliary contacts to break the trip coil current on breaker opening, thus easing the duty on the protection contacts. In cases such as operation of disconnectors, or retrofitting, it may be that 52a contacts are either unavailable or unreliable. High break contacts can be used to break the trip coil current in these applications.

3. Breaker Fail

   The technique to use 52a contacts in trip circuits was described above. However, in the event of failure of the local circuit breaker (stuck breaker), or defective auxiliary contacts (stuck contacts), the 52a contact action is incorrect. The interrupting duty at the local breaker then falls on the relay output contacts which may not be rated to perform this duty. MiCOM high break contacts will avoid the risk of burnt relay contacts.

4. Initiation of Teleprotection

   The MiCOM high break contacts also offer fast making. This can provide faster tripping: additionally, fast keying of teleprotection is a benefit. Fast keying bypasses the usual contact operation time, such that permissive, blocking and intertrip commands can be routed faster.

2.5.5 Input/Output (4 + 4) Relay Board (P64x - P642/P643/P645 only)

The input/output relay board has four isolated digital inputs and four output relays. Two of the relays have normally open contacts and two have changeover contacts. The output relays are driven from the 22 V power supply line. The relays' state is written to or read from using the parallel data bus.

This board is an option on the P642, giving 12 opto inputs and 12 output relay contacts.

2.6 Resistance Temperature Detector (RTD) Board (P64x - P642/P643/P645 only)

The RTD (Resistance Temperature Detector) board is an order option. It is used to monitor the temperature readings from up to ten PT100 RTDs that are each connected using a 3-wire connection. The board is powered from the 22 V power rail that is used to drive the output relays. The RTD board includes two redundant channels that are connected to high stability resistors to provide reference readings. These are used to check the operation of the RTD board. The temperature data is read by the processor through the parallel data bus, and is used to provide thermal protection of the transformer windings.

2.7 IRIG-B Board (Optional)

The IRIG-B board is an order option which can be fitted to provide an accurate timing reference for the relay. The IRIG-B signal is connected to the board via a BNC connector on the back of the relay. The timing information is used to synchronize the relay's internal real-time clock to an accuracy of 1ms. The internal clock is then used for the time tagging of the event, fault maintenance and disturbance records.

The IRIG-B board can also be specified with a fiber optic transmitter/receiver which can be used for the rear communication port instead of the EIA(RS)485 electrical connection (IEC 60870 protocol only).

2.8 Second Rear Communications Board

The second rear comms/InterMiCOM board, and IRIG-B board are mutually exclusive since they use the same hardware slot. For this reason two versions of second rear comms board are available; one with an IRIG-B input and one without. The physical layout of the second rear comms board is shown in Figure 7 (P443/P446/P543/P544/P545/P546/P547/P642/P643/P645) and Figure 8 (P445).

2.8.1 P443/P446/P543/P544/P545/P546/P547/P642/P643/P645:

For relays with Courier, MODBUS, IEC60870-5-103 or DNP3 protocol on the first rear communications port there is the hardware option of a second rear communications port, which will run the Courier language. This can be used over one of three physical links: twisted pair K-Bus (non polarity sensitive), twisted pair EIA(RS)485 (connection polarity sensitive) or EIA(RS)232.

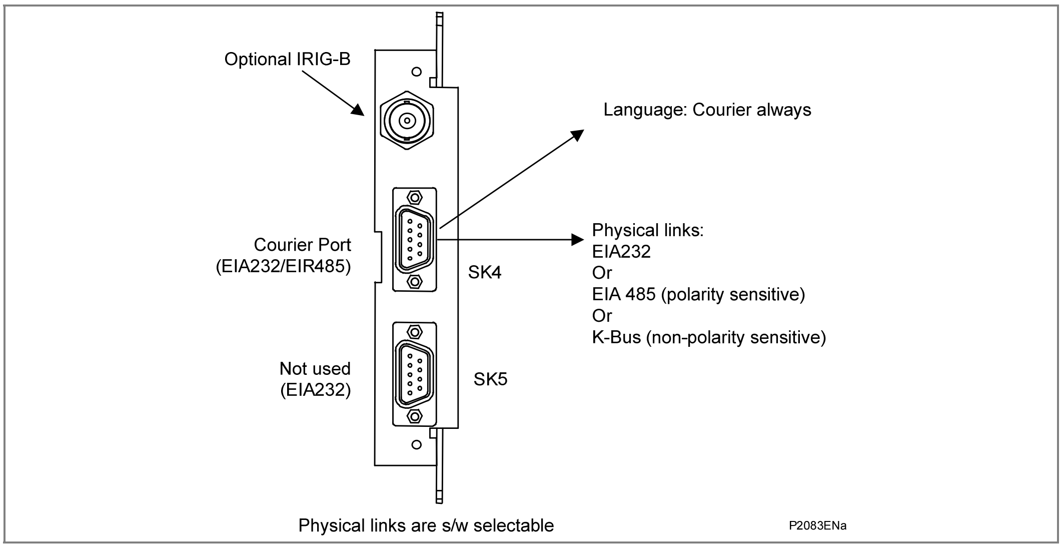

Optional IRIG-B
Language: Courier always
Courier Port
(EIA232/EIR485)
SK4
Physical links:
EIA232
Or
EIA 485 (polarity sensitive)
Or
K-Bus (non-polarity sensitive)
Not used
(EIA232)
SK5
Physical links are s/w selectable
P2083ENa

Figure 7 - Second rear comms board (optional) for P443/P446/P543/P544/P545/P546/P547/P642/P643/P645

2.8.2 P445 only:

On ordering this board within a relay, both second rear communications and InterMiCOM will become connection and setting options. The user may then enable either one, or both, as demanded by the installation.

- SK4: The second rear communications port runs the Courier language. This can be used over one of three physical links: twisted pair K-Bus (non polarity sensitive), twisted pair EIA(RS)485 (connection polarity sensitive) or EIA(RS)232.
- SK5: The InterMiCOM board is used to connect to an EIA(RS)232 link, allowing up to eight programmable signaling bits to be transferred from/to the remote line end relay. A suitable EIA(RS)232 link must exist between the two line ends, for example a MODEM, or via a compatible multiplexer (check compatibility before ordering the relay).

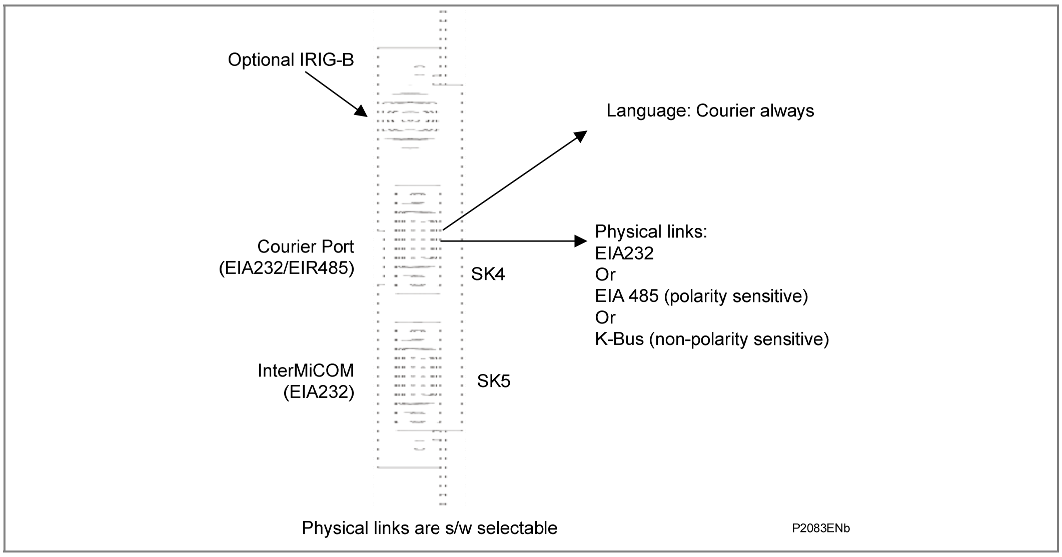

Optional IRIG-B
Language: Courier always
Courier Port
(EIA232/EIR485)
SK4
Physical links:
EIA232
Or
EIA 485 (polarity sensitive)
Or
K-Bus (non-polarity sensitive)
InterMiCOM
(EIA232)
SK5
Physical links are s/w selectable
P2083ENb

Figure 8 - Second rear comms board (optional) for P445

2.9 Ethernet Board

The optional Ethernet board (ZN0049) has 3 variants which support the IEC 61850 and DNP3 over Ethernet implementation:

- 100 Mbits/s Fiber Optic + 10/100 Mbits/s Copper
- 100 Mbits/s Fiber Optic + 10/100 Mbits/s Copper + modulated IRIG-B
- 100 Mbits/s Fiber Optic + 10/100 Mbits/s Copper + un-modulated IRIG-B

This card is fitted into Slot A of the relay, which is the optional communications slot. Each Ethernet card has a unique MAC address used for Ethernet communications. This is printed on the rear of the card, alongside the Ethernet sockets.

The 100 Mbits/s Fiber Optic ports use ST-type connectors and are suitable for 1300nm multi-mode fiber type.

Copper ports use RJ45 type connectors. When using copper Ethernet, it is important to use Shielded Twisted Pair (STP) or Foil Twisted Pair (FTP) cables, to shield the IEC 61850 communications against electromagnetic interference. The RJ45 connector at each end of the cable must be shielded, and the cable shield must be connected to this RJ45 connector shield, so that the shield is grounded to the relay case. Both the cable and the RJ45 connector at each end of the cable must be Category 5 minimum, as specified by the IEC 61850 standard. It is recommended that each copper Ethernet cable is limited to a maximum length of 3 meters and confined within one bay/cubicle.

When using DNP 3.0 or IEC 61850 communications through the Ethernet card, the rear EIA(RS)485 and front EIA(RS)232 ports are also available for simultaneous use, both using the Courier protocol.

The physical layout of the Ethernet board is shown in Figure 9.

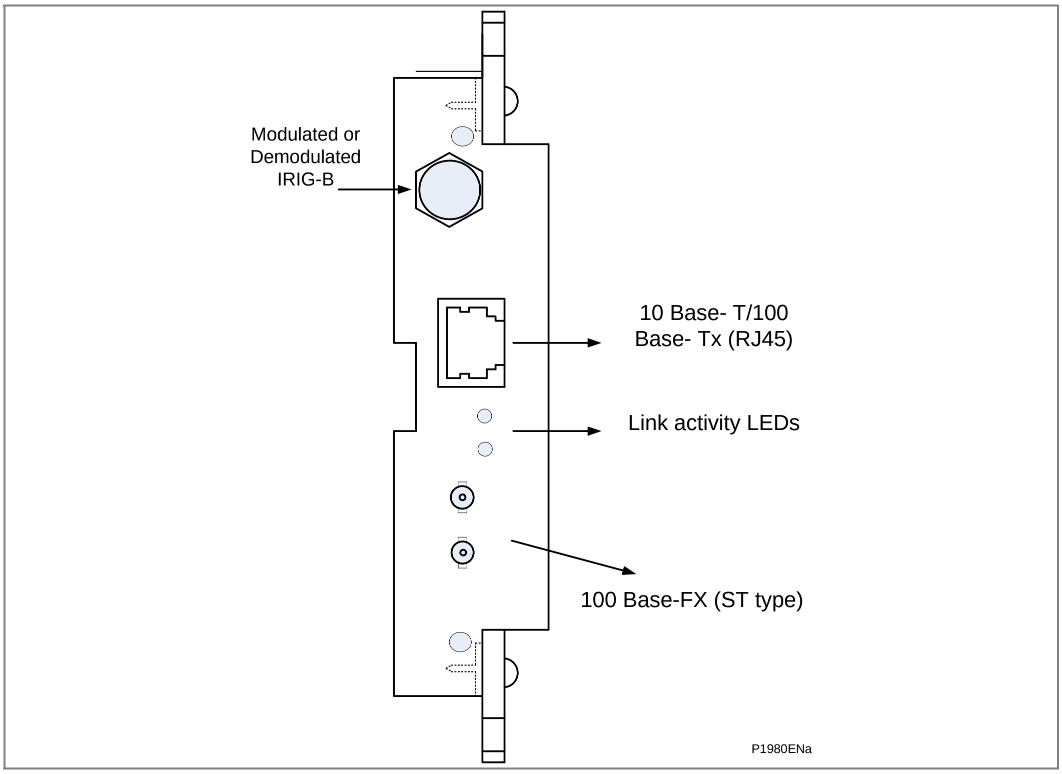


Figure 9 - Ethernet board (optional)

2.10 Mechanical Layout

The case materials of the relay are constructed from pre-finished steel that has a conductive covering of aluminum and zinc. This provides good earthing at all joints giving a low impedance path to earth that is essential for performance in the presence of external noise. The boards and modules use a multi-point earthing strategy to improve the immunity to external noise and minimize the effect of circuit noise. Ground planes are used on boards to reduce impedance paths and spring clips are used to ground the module metalwork.

Heavy duty terminal blocks are used at the rear of the relay for the current and voltage signal connections. Medium duty terminal blocks are used for the digital logic input signals, the output relay contacts, the power supply and the rear communication port. A BNC connector is used for the optional IRIG-B signal. 9-pin and 25-pin female D-connectors are used at the front of the relay for data communication.

Inside the relay the PCBs plug into the connector blocks at the rear, and can be removed from the front of the relay only. The connector blocks to the relay’s CT inputs are provided with internal shorting links inside the relay which will automatically short the current transformer circuits before they are broken when the board is removed.

The front panel consists of a membrane keypad with tactile dome keys, an LCD and 12 LEDs mounted on an aluminum backing plate.

2.11 Current Loop Input Output Board (CLIO) (P64x - P642/P643/P645 only)

The Current Loop Input Output (CLIO) board is an order option. The CLIO board is powered from the 22 V power rail that is used to drive the output relays.

Four analog (or current loop) inputs are provided for transducers with ranges of 0 to 1 mA, 0 to 10 mA, 0 to 20 mA or 4 to 20 mA. The input current data is read by the processor through the parallel data bus, and is used to provide measurements from various transducers such as vibration monitors, tachometers and pressure transducers.

For each of the four current loop inputs there are two separate input circuits, 0 to 1 mA and 0 to 20 mA. The latter is also used for 0 to 10 mA and 4 to 20 mA transducer inputs. The anti-alias filters have a nominal cut-off frequency (3 dB point) of 23 Hz to reduce power system interference from the incoming signals. Four analog current outputs are provided with ranges of 0 to 1 mA, 0 to 10 mA, 0 to 20 mA or 4 to 20 mA which can alleviate the need for separate transducers. These may be used to feed standard moving coil ammeters for analog indication of certain measured quantities or into a SCADA using an existing analog RTU.

Each of the four current loop outputs provides one 0 to 1 mA output, one 0 to 20 mA output and one common return. Suitable software scaling of the value written to the board allows the 0 to 20 mA output to also provide 0 to 10 mA and 4 to 20 mA. Screened leads are recommended for use on the current loop output circuits.

The refresh interval for the outputs is nominally 50 ms. Any measurements that do not fit this timing are updated once every second.

All external connections to the current loop I/O board are made using the same 15-way light duty I/O connector SL3.5/15/90F used on the RTD board. Two such connectors are used, one for the current loop outputs and one for the current loop inputs.

The I/O connectors accommodate wire sizes in the range 1/0.85 mm (0.57 mm^2) to 1/1.38 mm (1.5 mm^2) and their multiple conductor equivalents. The use of screened cable is recommended. The screen terminations should be connected to the case earth of the relay.

Basic Insulation (300 V) is provided between analog inputs or outputs and earth, and between analog inputs and outputs. However, there is no insulation between one input and another or one output and another.

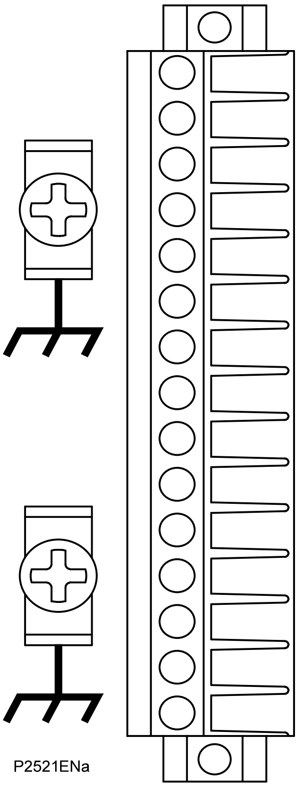
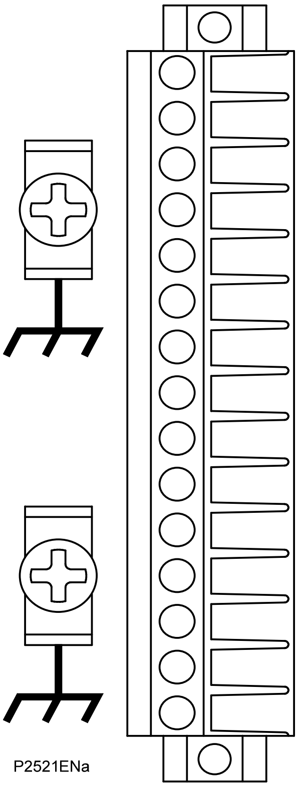
Connection	IO blocks	Connection
Outputs Screen channel 1 Screen channel 2 Screen channel 3 Screen channel 4		0 - 10/0 - 20/4 – 20 mA channel 1 0 – 1 mA channel 1 Common return channel 1 0 - 10/0 - 20/4 – 20 mA channel 2 0 – 1 mA channel 2 Common return channel 2 0 - 10/0 - 20/4 – 20 mA channel 3 0 – 1 mA channel 3 Common return channel 3 0 - 10/0 - 20/4 – 20 mA channel 4 0 – 1 mA channel 4 Common return channel 4
Inputs Screen channel 1 Screen channel 2 Screen channel 3 Screen channel 4		0 - 10/0 - 20/4 – 20 mA channel 1 0 – 1 mA channel 1 Common channel 1 0 - 10/0 - 20/4 – 20 mA channel 2 0 – 1 mA channel 2 Common channel 2 0 - 10/0 - 20/4 – 20 mA channel 3 0 – 1 mA channel 3 Common channel 3 0 - 10/0 - 20/4 – 20 mA channel 4 0 – 1 mA channel 4 Common channel 4

Table 7 - Current Loop Input Output (CLIO) board

3 RELAY SOFTWARE

The software can be considered to be made up of four sections:

- The real-time operating system
- The system services software
- The platform software
- The protection & control software

This section describes in detail the latter two of these, the platform software and the protection & control software, which between them control the functional behavior of the relay. Figure 10 shows the structure of the relay software.

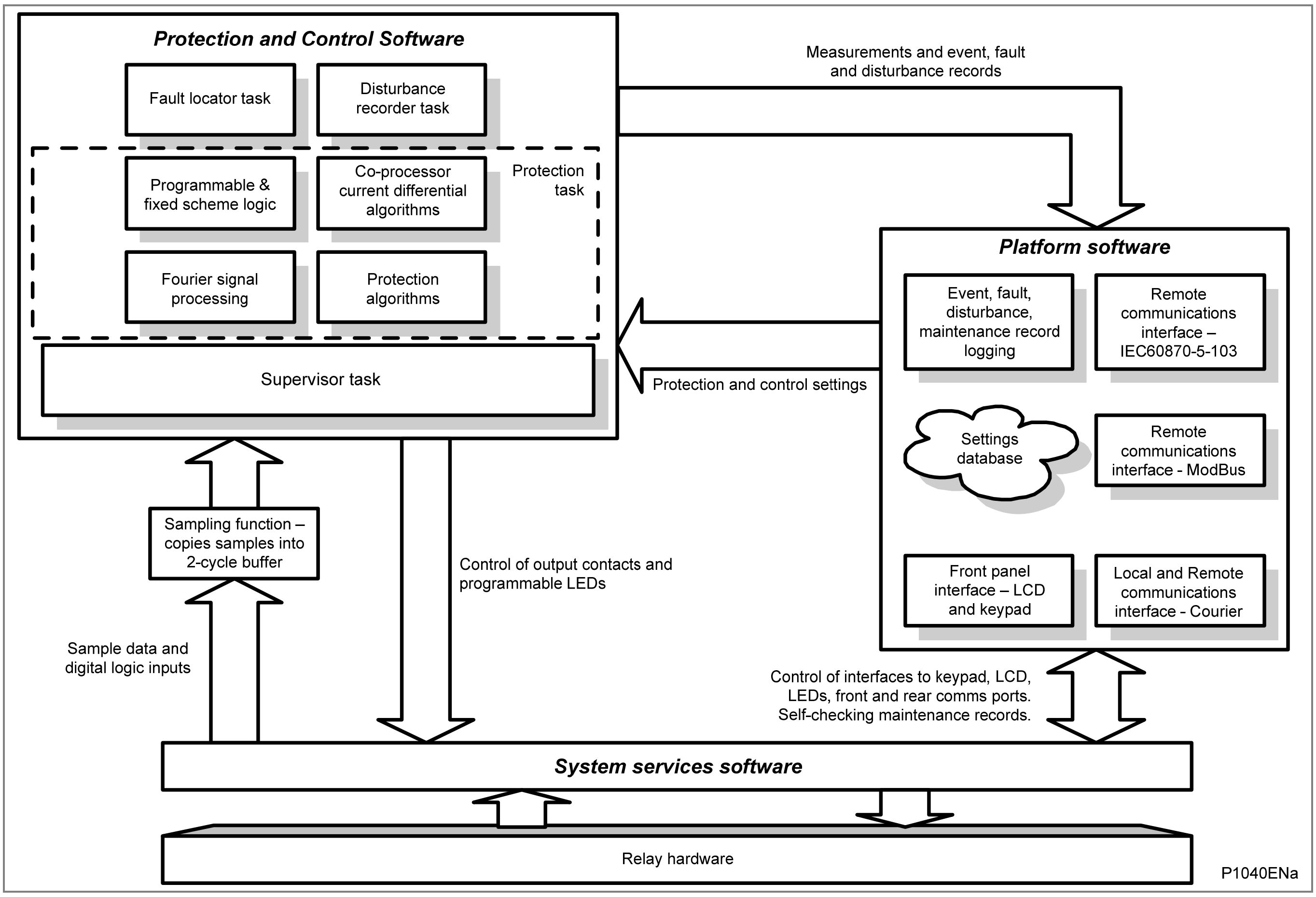

Protection and Control Software
Fault locator task
Disturbance recorder task
Programmable & fixed scheme logic
Co-processor current differential algorithms
Protection task
Fourier signal processing
Protection algorithms
Supervisor task
Measurements and event, fault and disturbance records
Platform software
Event, fault, disturbance, maintenance record logging
Remote communications interface – IEC60870-5-103
Protection and control settings
Settings database
Remote communications interface - ModBus
Front panel interface – LCD and keypad
Local and Remote communications interface - Courier
Sampling function – copies samples into 2-cycle buffer
Sample data and digital logic inputs
Control of output contacts and programmable LEDs
Control of interfaces to keypad, LCD, LEDs, front and rear comms ports. Self-checking maintenance records.
System services software
Relay hardware
P1040ENa

Figure 10 - Relay software structure (all products except P64x - P642/P643/P645)

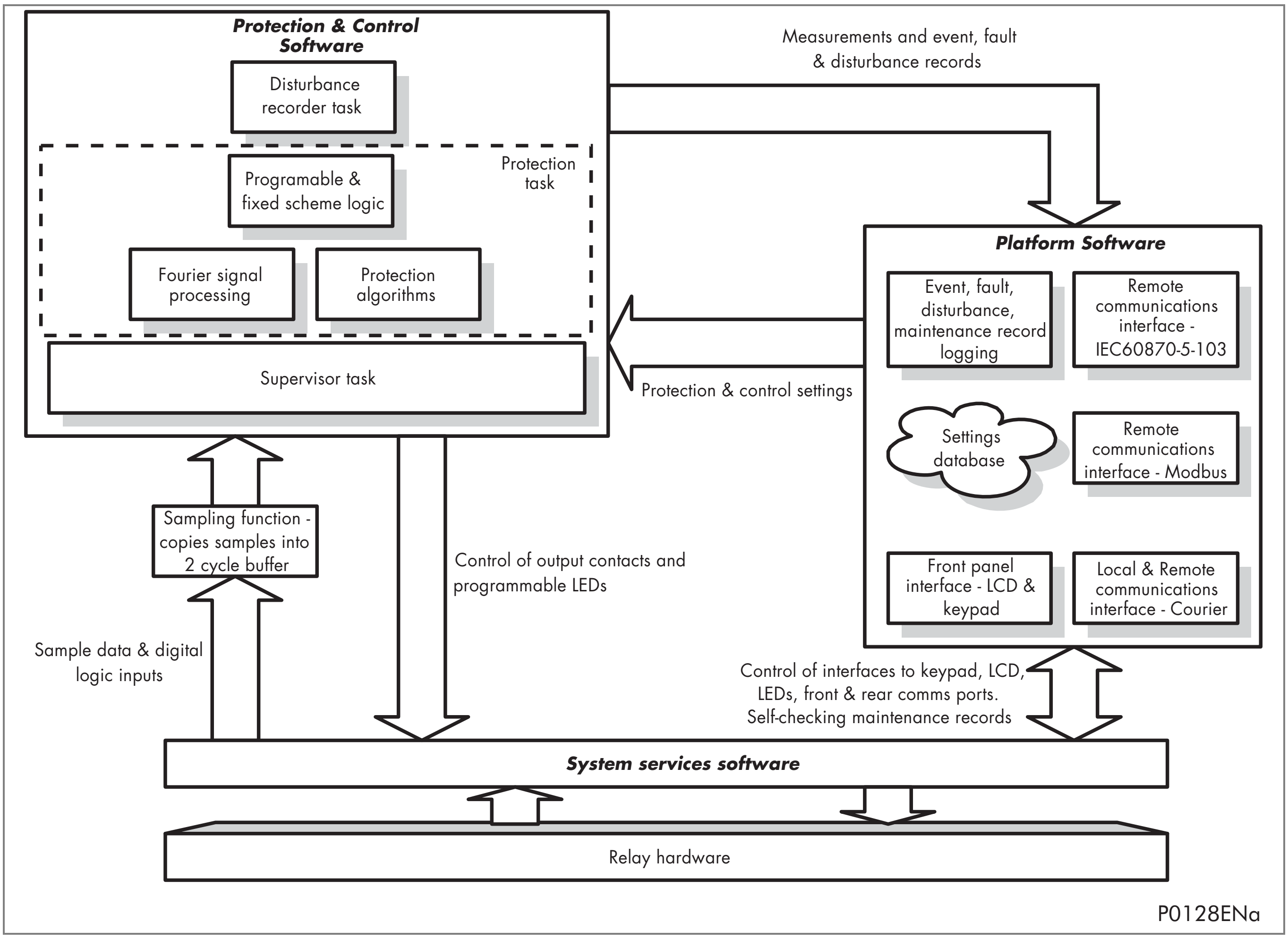

Protection & Control Software
Disturbance recorder task
Programable & fixed scheme logic
Protection task
Fourier signal processing
Protection algorithms
Supervisor task
Measurements and event, fault & disturbance records
Platform Software
Event, fault, disturbance, maintenance record logging
Remote communications interface - IEC60870-5-103
Protection & control settings
Settings database
Remote communications interface - Modbus
Front panel interface - LCD & keypad
Local & Remote communications interface - Courier
Sampling function - copies samples into 2 cycle buffer
Control of output contacts and programmable LEDs
Sample data & digital logic inputs
Control of interfaces to keypad, LCD, LEDs, front & rear comms ports. Self-checking maintenance records
System services software
Relay hardware
P0128ENa

Figure 11 - Relay software structure (P64x - P642/P643/P645 only)

3.1 Real-Time Operating System

The software is split into tasks; the real-time operating system is used to schedule the processing of the tasks to ensure that they are processed in the time available and in the desired order of priority. The operating system is also responsible in part for controlling the communication between the software tasks through the use of operating system messages.

3.2 System Services Software

Figure 10 shows the system services software provides the interface between the relay's hardware and the higher-level functionality of the platform software and the protection & control software. For example, the system services software provides drivers for items such as the LCD display, the keypad and the remote communication ports, and controls the boot of the processor and downloading of the processor code into SRAM from flash EPROM at power up.

3.3 Platform Software

The platform software has these main functions:

- To control the logging of records that are generated by the protection software, including alarms and event, fault, and maintenance records
- To store and maintain a database of all of the relay's settings in non-volatile memory
- To provide the internal interface between the settings database and each of the relay's user interfaces, i.e. the front panel interface and the front and rear communication ports, using whichever communication protocol has been specified (Courier, IEC 60870-5-103, DNP3.0). The P64x (P642/P643/P645) products also include the MODBUS protocol).

3.3.1 Record Logging

The logging function is provided to store all alarms, events, faults and maintenance records. The records for all of these incidents are logged in battery backed-up SRAM in order to provide a non-volatile log of what has happened. The relay maintains four logs: one each for up to 96 alarms, 512 event records, 5 fault records and 5 maintenance records. The logs are maintained such that the oldest record is overwritten with the newest record. The logging function can be initiated from the protection software or the platform software is responsible for logging of a maintenance record in the event of a relay failure. This includes errors that have been detected by the platform software itself or error that are detected by either the system services or the protection software function. See also the section on supervision and diagnostics later in this chapter.

3.3.2 Settings Database

The settings database contains all of the settings and data for the relay, including the protection, disturbance recorder and control and support settings. The settings are maintained in non-volatile memory. The platform software's management of the settings database includes the responsibility of ensuring that only one user interface modifies the settings of the database at any one time. This feature is employed to avoid conflict between different parts of the software during a setting change. For changes to protection settings and disturbance recorder settings, the platform software operates a 'scratchpad' in SRAM memory. This allows a number of setting changes to be applied to the protection elements, disturbance recorder and saved in the database in non-volatile memory. If a setting change affects the protection and control task, the database advises it of the new values.

3.3.3 Database Interface

The other function of the platform software is to implement the relay's internal interface between the database and each of the relay's user interfaces. The database of settings and measurements must be accessible from all of the relay's user interfaces to allow read and modify operations. The platform software presents the data in the appropriate format for each user interface.

3.4 Protection and Control Software

The protection and control software task is responsible for processing all of the protection elements and measurement functions of the relay. To achieve this it has to communicate with both the system services software and the platform software as well as organize its own operations. The protection software has the highest priority of any of the software tasks in the relay in order to provide the fastest possible protection response. The protection & control software has a supervisor task that controls the start-up of the task and deals with the exchange of messages between the task and the platform software.

3.4.1 Overview - Protection and Control Scheduling

The Protection and Control Scheduling process works slightly differently from one product type to another.

All Products except the P64x - P642/P643/P645 products.
After initialization at start-up, the protection and control task on the main processor board is suspended until the co-processor board re-starts via an interrupt. Where the co-processor board has failed, the protection task will automatically start after six analog samples have been received. In normal operation the task will be re-started by the co-processor 16 times per cycle. The acquisition of samples on the main processor board is controlled by a ‘sampling function’ which is called by the system services software and takes each set of new samples from the input module and stores them in a two-cycle buffer, these samples are also stored concurrently by the co-processor.

P64x - P642/P643/P645 products only
After initialization at start-up, the protection and control task waits until there are enough samples to process. The sampling function is called by the system services software and takes each set of new samples from the input module and stores them in a two-cycle buffer. The protection and control software resumes execution when the number of unprocessed samples in the buffer reaches a certain number. Samples are taken 24 times every power cycle. Every 6 samples the protection task is executed (4 times per cycle). The protection elements are split into groups so that different elements are processed each time, and every element is processed at least once per cycle. The protection and control software is suspended again when all of its processing on a set of samples is complete. This allows operations by other software tasks to take place.

3.4.2 Signal Processing

The sampling function provides filtering of the digital input signals from the opto-isolators and frequency tracking of the analog signals.

The frequency tracking of the analog input signals is achieved by a recursive Fourier algorithm which is applied to one of the input signals, and works by detecting a change in the measured signal’s phase angle. The calculated value of the frequency is used to modify the sample rate being used by the input module so as to achieve a constant sample rate of 48 samples per cycle (see note) of the power waveform. The value of the frequency is also stored for use by the protection and control task.

Note *24 samples for the P64x - P642/P643/P645 products.*

When the protection and control task is re-started by the sampling function, it calculates the Fourier components for the analogue signals. The Fourier components are calculated using a one-cycle, 48-sample (see note) Discrete Fourier Transform (DFT). The DFT is always calculated using the last cycle of samples from the 2-cycle buffer, i.e. the most recent data is used. The DFT used in this way extracts the power frequency fundamental component from the signal and produces the magnitude and phase angle of the fundamental in rectangular component format. The DFT provides an accurate measurement of the fundamental frequency component, and effective filtering of harmonic frequencies and noise. This performance is achieved in conjunction with the relay input module which provides hardware anti-alias filtering to attenuate frequencies above the half sample rate, and frequency tracking to maintain a sample rate of 48 samples per cycle (see note). The Fourier components of the input current and voltage signals are stored in memory so that they can be accessed by all of the protection elements' algorithms. The samples from the input module are also used in an unprocessed form by the disturbance recorder for waveform recording and to calculate true rms values of current, voltage and power for metering purposes.

Note *24 samples for the P64x - P642/P643/P645 products.*

3.4.3 Main Protection Digital Filtering - Co-Processor Board (not P64x - P642/P643/P645)

All of the processing for the various protection algorithms is performed on the co-processor board.

3.4.3.1 Differential Protection (P543/P544/P545/P546 only)

The differential protection is based on the relays at the line ends exchanging data messages four times per cycle. To achieve this the co-processor takes the frequency-tracked samples at 48 samples per cycle from the input board and converts these to 8 samples per cycle based on the nominal frequency (i.e. not frequency tracked). The co-processor calculates the Fourier transform of the fixed rate samples after every sample, using a one-cycle window. This generates current measurements eight times per cycle which are used for the differential protection algorithm and transmitted to the remote relay(s) using the HDLC (High-level Data Link Control) communication protocol.

The co-processor is also responsible for managing intertripping commands via the communication link, and re-configuration instigated from the remote relay(s). Data exchange between the co-processor board and the main processor board is achieved through the use of shared memory on the co-processor board. When the main processor accesses this memory, the co-processor is temporarily halted. After the co-processor code has been copied onto the board at initialization, the main traffic between the two boards consists of setting change information, commands from the main processor, differential protection measurements and output data.

3.4.3.2 Phase Comparison Protection (P547 only)

The current and voltage inputs are filtered, using Finite Impulse Response (FIR) digital filters to reduce the effects of non-power frequency components in the input signals, such as DC offsets in current waveforms, and Capacitor Voltage Transformer (CVT) transients in the voltages.

- The P547 80TE uses a one-cycle filter using 48 coefficients. The Phase comparison protection is performed every 3 samples using this data.

3.4.3.3 Distance Protection (not P64x - P642/P643/P645)

The current and voltage inputs are filtered, using Finite Impulse Response (FIR) digital filters to reduce the effects of non-power frequency components in the input signals, such as DC offsets in current waveforms, and Capacitor Voltage Transformer (CVT) transients in the voltages.

- The P44y/P445 relay uses a combination of a ¼-cycle filter using 12 coefficients, a ½-cycle filter using 24 coefficients, and a one-cycle filter using 48 coefficients.
- The P54x uses a combination of a ¼-cycle filter using 12 coefficients, a ½-cycle filter using 24 coefficients, and a one-cycle filter using 48 coefficients.

The relay automatically performs intelligent switching in the application of the filters, to select the best balance of removal of transients with fast response.

Note	*The protection elements themselves then perform additional filtering, for example implemented by the trip count strategy.*

Figure 12 shows the frequency response of the 12, 24 and 48 coefficient filters, noting that all have a gain of unity at the fundamental:

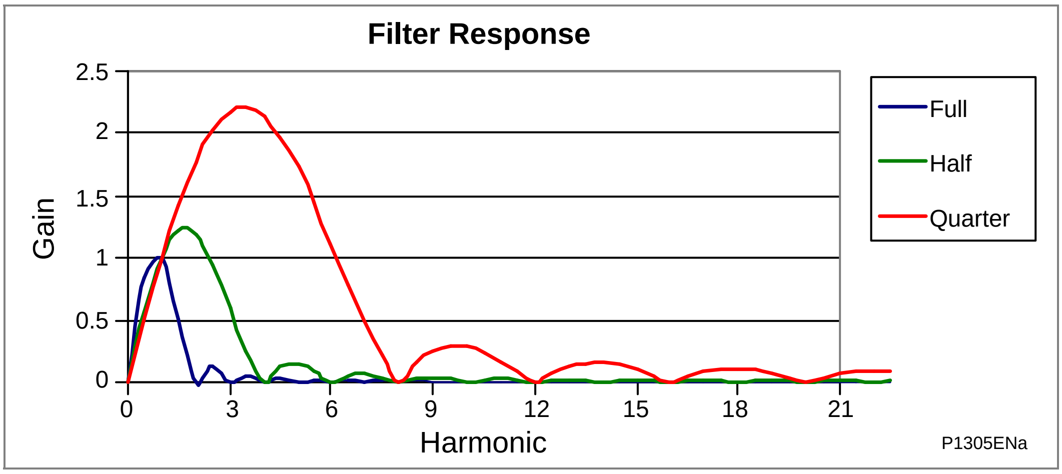


Figure 12 - Frequency response of filters (not P64x - P642/P643/P645)

3.4.3.4 Fourier Filtering

All backup protection and measurement functions use one-cycle Fourier digital filtering to extract the power frequency component. This filtering is performed on the main processor board.

3.4.4 Frequency Response for P64x - P642/P643/P645

With the exception of the RMS measurements, all other measurements and protection functions are based on the Fourier-derived fundamental component. The fundamental component is extracted by using a 24-sample DFT. This gives good harmonic rejection for frequencies up to the 23rd harmonic. The 23rd is the first predominant harmonic that is not attenuated by the Fourier filter and this is known as an ‘Alias’. However, the Alias is attenuated by approximately 85% by an additional, analog, ‘anti-aliasing’ filter (low pass filter). The combined affect of the anti-aliasing and Fourier filters is shown in Figure 13.

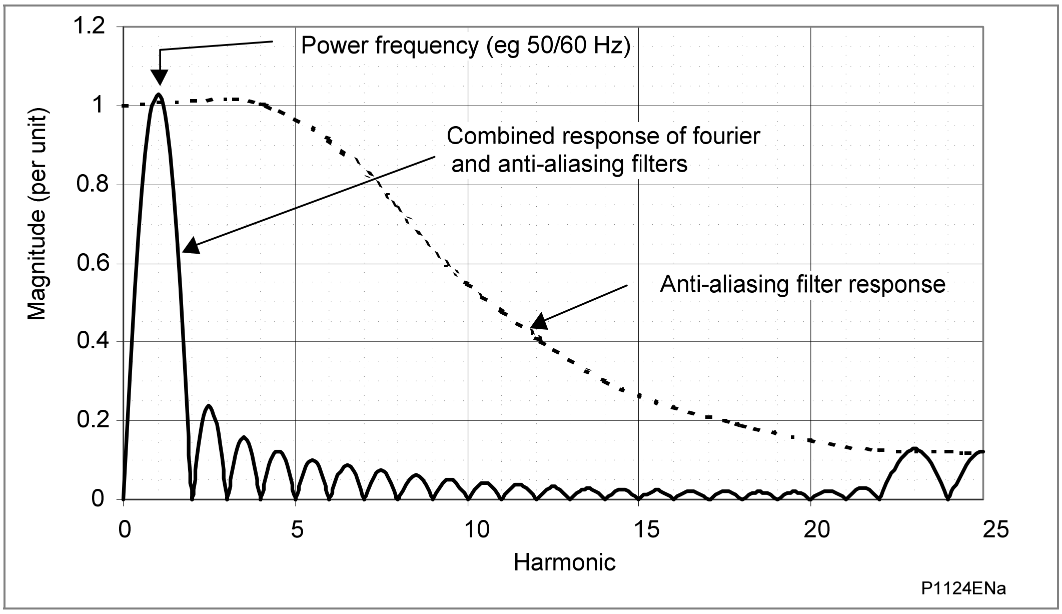


Figure 13 - Frequency response (for P64x - P642/P643/P645

For power frequencies that are not equal to the selected rated frequency, the harmonics are attenuated to zero amplitude. For small deviations of ±1Hz, this is not a problem but to allow for larger deviations, frequency tracking is used.

Frequency tracking automatically adjusts the sampling rate of the analog to digital conversion to match the applied signal. In the absence of a suitable signal to amplitude track, the sample rate defaults to the selected rated frequency (Fn). If the a signal is in the tracking range of 45 to 66 Hz, the relay locks onto the signal and the measured frequency coincides with the power frequency as shown in Figure 13. The outputs for harmonics up to the 23rd are zero. The relay frequency tracks off any voltage or current in the order VA/VB/VC/IA/IB/IC down to 10% Vn for voltage and 5%In for current.

3.4.5 Programmable Scheme Logic (PSL)

The purpose of the Programmable Scheme Logic (PSL) is to allow the relay user to configure an individual protection scheme to suit their own particular application. This is achieved through the use of programmable logic gates and delay timers. To allow greater flexibility the PSL is part of the relay protection setting group.

The input to the PSL is any combination of the status of the digital input signals from the opto-isolators on the input board, the outputs of the protection elements, e.g. protection starts and trips, and the outputs of the fixed protection scheme logic. The fixed scheme logic provides the relay’s standard protection schemes. The PSL itself consists of software logic gates and timers. The logic gates can be programmed to perform a range of different logic functions and can accept any number of inputs. The timers are used either to create a programmable delay, and/or to condition the logic outputs, e.g. to create a pulse of fixed duration on the output regardless of the length of the pulse on the input. The outputs of the PSL are the LEDs on the front panel of the relay and the output contacts at the rear.

The execution of the PSL logic is event driven; the logic is processed whenever any of its inputs change, for example as a result of a change in one of the digital input signals or a trip output from a protection element. Also, only the part of the PSL logic that is affected by the particular input change that has occurred is processed. This reduces the amount of processing time that is used by the PSL. The protection and control software updates the logic delay timers and checks for a change in the PSL input signals every time it runs.

This system provides flexibility for the user to create their own scheme logic design. However, it also means that the PSL can be configured into a very complex system, and because of this setting of the PSL is implemented through the PC support package MiCOM S1 Studio.

3.4.6 Function Key Interface (P643 and P645 only)

The ten function keys interface directly into the PSL as digital input signals and are processed based on the PSLs event-driven execution. However, a change of state is only recognized when a key press is executed, on average for longer than 200 ms. The time to register a change of state depends on whether the function key press is executed at the start or the end of a protection task cycle, with the additional hardware and software scan time included. A function key press can provide a latched (toggled mode) or output on key press only (normal mode) depending on how it is programmed and can be configured to individual protection scheme requirements. The latched state signal for each function key is written to non-volatile memory and read from non-volatile memory during relay power up, allowing the function key state to be reinstated after power-up if the relay power is lost.

3.4.6.1 PSL Data - Attaching A Text Identifier for Version Traceability

In the PSL editor in MiCOM S1 Studio when a PSL file is downloaded to the relay the user can specify the group to download the file and a 32 character PSL reference description. This PSL reference is shown in the ‘Grp1/2/3/4 PSL Ref’ cell in the ‘PSL DATA’ menu in the relay. The download date and time and file checksum for each groups PSL file is also shown in the ‘PSL DATA’ menu in cells ‘Date/Time’ and ‘Grp 1/2/3/4 PSL ID’. The PSL data can be used to indicate if a PSL has been changed and thus be useful in providing information for version control of PSL files.

The default PSL Reference description is “Default PSL” followed by the model number, for example:

P443/: “Default PSL P443??????0yy0?” refers to the software version e.g. 40

P543/P544/P545/P546:
“Default PSL P54x??????0yy0?” refers to the software version e.g. 40

P547: “Default PSL P547??????0yy0?” refers to the software version e.g. 52

P642: “Default PSL P642??????0yy0?” refers to the software version e.g. 05

P643: “Default PSL P643??????0yy0?” refers to the software version e.g. 05

P645: “Default PSL P645??????0yy0?” refers to the software version e.g. 05

This is the same for all protection setting groups (since the default PSL is the same for all groups). Since the LCD display (bottom line) only has space for 16 characters the display must be scrolled to see all 32 characters of the PSL Reference description.

The default date and time is the date and time when the defaults were loaded from flash into EEPROM.

Note	*The PSL DATA column information is visible via the relay front panel interface or over the Courier communications protocol.*

3.4.7 Event, Fault and Maintenance Recording

A change in any digital input signal or protection element output signal is used to indicate that an event has taken place. When this happens, the protection and control task sends a message to the supervisor task to show that an event is available to be processed. The protection and control task writes the event data to a fast buffer in SRAM that is controlled by the supervisor task. When the supervisor task receives either an event or fault record message, it instructs the platform software to create the appropriate log in battery backed-up SRAM. The supervisor's buffer is faster than battery backed-up SRAM, therefore the protection software is not delayed waiting for the records to be logged by the platform software. However, if a large number of records to be logged are created in a short time, some may be lost if the supervisor's buffer is full before the platform software is able to create a new log in battery backed-up SRAM. If this occurs, an event is logged to indicate this loss of information.

Maintenance records are created in a similar manner with the supervisor task instructing the platform software to log a record when it receives a maintenance record message. However, it is possible that a maintenance record may be triggered by a fatal error in the relay, in which case it may not be possible to successfully store a maintenance record, depending on the nature of the problem. *See section 4 -* Self Testing and Diagnostics*.*

Fault records are stored in the sequence of events. They can be viewed locally or remotely and include:

- Faulty phase(s)
- Protection Tripped
- Protection Started
- Fault duration
- Fault type (internal or external fault)
- Operating time
- Primary or Secondary RMS values of prefault phase and neutral currents or angle of each winding
- Primary or Secondary RMS values of fault phase and neutral currents or angle of each winding
- Primary or Secondary RMS values of differential and biased current of each phase

3.4.8 Disturbance Recorder

The disturbance recorder operates as a separate task from the protection and control task. It can record the waveforms for up to 12 (see note) calibrated analog channels and the values of up to 32 digital signals.

Note	*only up to 8 channels for the P445, and up to 22 channels for the P64x (P642/P643/P645).*

Several seconds of data can be recorded and the recording time is user selectable.

- Up to 50 seconds can be recorded for most relays - a minimum number of 5 records of 10 seconds each and a maximum of 50 records with 10 seconds each can be set.
- Up to 10 seconds of data can be recorded for the P445 and the P64x (P642/P643/P645_.

The disturbance recorder is supplied with data by the protection and control task once per cycle. The disturbance recorder collates the data that it receives into a disturbance record of the required length. The disturbance records can be extracted by MiCOM S1 Studio which can also store the data in COMTRADE format, thus allowing the use of other packages to view the recorded data.

3.4.9 Fault Locator

The fault locator uses a 12-cycle buffer of the analog input signals and returns the calculated location of the fault to the protection and control task which includes it in the fault record for the fault. The prefault and fault voltages and currents are calculated by the fault locator, there are also presented within the fault record. When the fault record is complete (i.e. includes the fault location), the protection and control task can send a message to the supervisor task to log the fault record.

4 SELF TESTING AND DIAGNOSTICS

The relay includes a number of self-monitoring functions to check the operation of its hardware and software when it is in service. These are included so that if an error or fault occurs within the relay's hardware or software, the relay is able to detect and report the problem and attempt to resolve it by performing a re-boot. This involves the relay being out of service for a short period of time which is indicated by the 'Healthy' LED on the front of the relay being extinguished and the watchdog contact at the rear operating. If the restart fails to resolve the problem, then the relay will take itself permanently out of service. Again this will be indicated by the LED and watchdog contact.

If a problem is detected by the self-monitoring functions, the relay attempts to store a maintenance record in battery backed-up SRAM to allow the nature of the problem to be notified to the user.

The self-monitoring is implemented in two stages: firstly a thorough diagnostic check which is performed when the relay is booted-up, e.g. at power-on, and secondly a continuous self-checking operation which checks the operation of the relay's critical functions whilst it is in service.

4.1 Start-Up Self-Testing

The self-testing which is carried out when the relay is started takes a few seconds to complete, during which time the relay's protection is unavailable. This is signaled by the 'Healthy' LED on the front of the relay which will illuminate when the relay has passed all of the tests and entered operation. If the testing detects a problem, the relay will remain out of service until it is manually restored to working order.

The operations that are performed at start-up are as follows:

- System Boot
- Initialization Software
- Platform Software Initialization & Monitoring

4.1.1 System Boot

The integrity of the flash EPROM memory is verified using a checksum before the program code and data stored in it is copied into SRAM to be used for execution by the processor. When the copy has been completed the data then held in SRAM is compared to that in the flash EPROM to ensure that the two are the same and that no errors have occurred in the transfer of data from flash EPROM to SRAM. The entry point of the software code in SRAM is then called which is the relay initialization code.

4.1.2 Initialization Software

The initialization process includes the operations of initializing the processor registers and interrupts, starting the watchdog timers (used by the hardware to determine whether the software is still running), starting the real-time operating system and creating and starting the supervisor task. In the course of the initialization process the relay checks:

- The status of the battery
- The integrity of the battery backed-up SRAM that is used to store event, fault and disturbance records
- The voltage level of the field voltage supply which is used to drive the opto-isolated inputs
- The operation of the LCD controller
- The watchdog operation
- For all products (except the P64x - P642/P643/P645):

  At the conclusion of the initialization software the supervisor task begins the process of starting the platform software. The checking that is made in the process of starting the co-processor board is as follows:

  - A check is made for the presence of, and a valid response from, the co-processor board
  - The SRAM on the co-processor board is checked with a test bit pattern before the co-processor code is transferred from the flash EPROM

  Any of these checks which produces an error results in the co-processor board being left out of service and the relay relying on the other protection functions which are provided by the main processor board.

4.1.3 Platform Software Initialization & Monitoring

In starting the platform software, the relay checks the integrity of the data held in non-volatile memory with a checksum, the operation of the real-time clock, and the IRIG-B board if fitted. The final test that is made concerns the input and output of data; the presence and healthy condition of the input board is checked and the analog data acquisition system is checked through sampling the reference voltage.

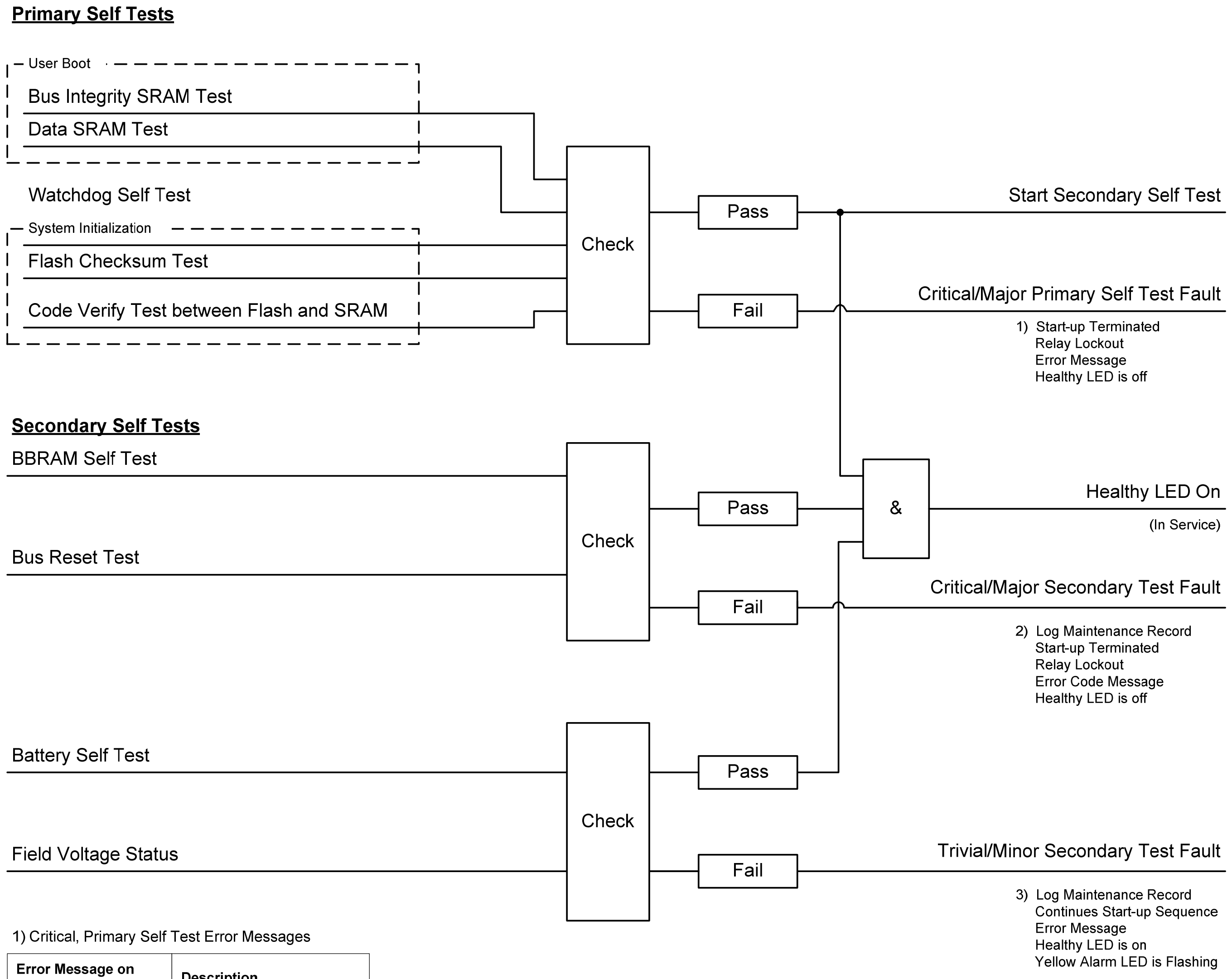
At the successful conclusion of all of these tests the relay is entered into service and the protection started-up.

4.2 Continuous Self-Testing

When the relay is in service, it continually checks the operation of the critical parts of its hardware and software. The checking is carried out by the system services software (see section on relay software earlier in this chapter) and the results reported to the platform software. The functions that are checked are as follows:

- The flash EPROM containing all program code and language text is verified by a checksum
- The code and constant data held in SRAM is checked against the corresponding data in flash EPROM to check for data corruption
- The SRAM containing all data other than the code and constant data is verified with a checksum
- The battery status
- The level of the 48V field voltage
- The integrity of the digital signal I/O data from the opto-isolated inputs and the relay contacts is checked by the data acquisition function every time it is executed. The operation of the analogue data acquisition system is continuously checked by the acquisition function every time it is executed, by means of sampling the reference voltages
- The operation of the IRIG-B board is checked, where it is fitted, by the software that reads the time and date from the board
- The operation of the Ethernet board is checked, where it is fitted, by the software on the main processor card. If the Ethernet board fails to respond an alarm is raised and the card is reset in an attempt to resolve the problem
- For the P64x - P642/P643/P645, the operation of the RTD board is checked by reading the temperature indicated by the reference resistors on the two spare RTD channels

In the unlikely event that one of the checks detects an error within the relay’s subsystems, the platform software is notified and it will attempt to log a maintenance record in battery backed-up SRAM. If the problem is with the battery status or the IRIG-B board (or the RTD or CLIO boards on the P64x - P642/P643/P645), the relay will continue in operation. However, for problems detected in any other area the relay will initiate a shutdown and re-boot. This will result in a period of up to 5 seconds when the protection is unavailable, but the complete restart of the relay including all initializations should clear most problems that could occur. As described above, an integral part of the start-up procedure is a thorough diagnostic self-check. If this detects the same problem that caused the relay to restart, i.e. the restart has not cleared the problem, then the relay will take itself permanently out of service. This is indicated by the ‘Healthy’ LED on the front of the relay, which will extinguish, and the watchdog contact which will operate.


Primary Self Tests
User Boot
Bus Integrity SRAM Test
Data SRAM Test
Watchdog Self Test
System Initialization
Flash Checksum Test
Code Verify Test between Flash and SRAM
Check
Pass
Fail
Start Secondary Self Test
Critical/Major Primary Self Test Fault
1) Start-up Terminated
Relay Lockout
Error Message
Healthy LED is off
Secondary Self Tests
BBRAM Self Test
Bus Reset Test
Check
Pass
Fail
&
Healthy LED On
(In Service)
Critical/Major Secondary Test Fault
2) Log Maintenance Record
Start-up Terminated
Relay Lockout
Error Code Message
Healthy LED is off
Battery Self Test
Field Voltage Status
Check
Pass
Fail
Trivial/Minor Secondary Test Fault
3) Log Maintenance Record
Continues Start-up Sequence
Error Message
Healthy LED is on
Yellow Alarm LED is Flashing

1) Critical, Primary Self Test Error Messages

Error Message on User Interface	Description
Bus Fail	Integrity Bus Test Error
SRAM Fail	SRAM Test Error
Flash Fail (Checksum)	Flash Test Error detected in the flash structure
Code Verify Fail	Error in code comparison test flash
Watchdog fail	Watchdog circuit fails to operate

2) Critical, Secondary Self Test Error Messages

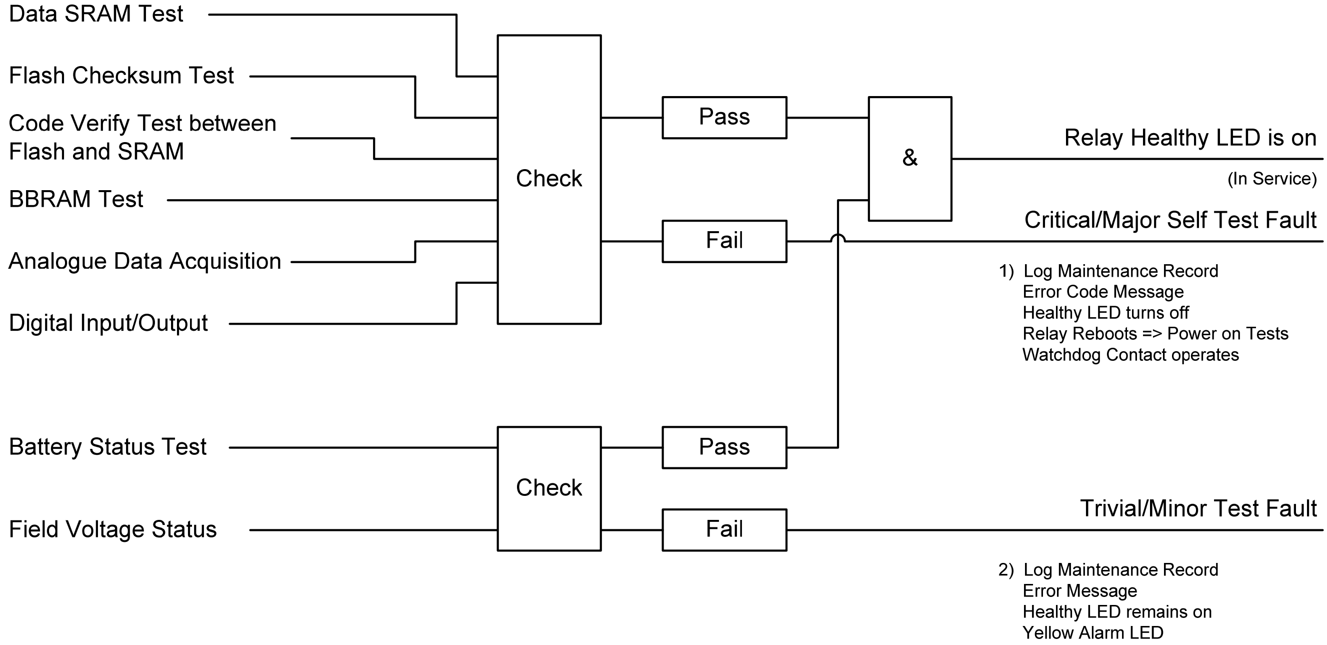
Error Code	Description
0x0C170017	The secondary self tests detected an error in the Battery Backed SRAM (BBRAM)
0x0C170018	The secondary self tests detected an error in the Bus Curcuit

3) Trivial, Secondary Power on Self Tests Alarm Indications

Alarm	Description
Battery Failure	The secondary self tests detected battery self test has failed
Field Volt Fail	The secondary self tests detected Field Voltage failure

P1625ENa

Figure 14 - Start-up self-testing logic (P64x - P642/P643/P645 only)


Data SRAM Test
Flash Checksum Test
Code Verify Test between Flash and SRAM
BBRAM Test
Analogue Data Acquisition
Digital Input/Output
Check
Pass
Fail
&
Relay Healthy LED is on
(In Service)
Critical/Major Self Test Fault
1) Log Maintenance Record
Error Code Message
Healthy LED turns off
Relay Reboots => Power on Tests
Watchdog Contact operates
Battery Status Test
Field Voltage Status
Check
Pass
Fail
Trivial/Minor Test Fault
2) Log Maintenance Record
Error Message
Healthy LED remains on
Yellow Alarm LED

1) Critical, Continuous Self-Test Error codes

Error Code	Description
0x0C160011	The continuous self tests detected an error in SRAM
0x0C160012	The continuous self tests detected an error in the Flash memory checksum
0x0C160013	The continuous self tests detected an error in the code comparison
0x0C160014	The continuous self tests detected an error in the Battery Backed RAM
0x0C1600A0	The continuous self tests detected an error in the acquisition card
0x0C1600Bn	The continuous self tests detected an error in relay card n (number from 0)
0x0C1600Cn	The continuous self tests detected an error in opto card n (number from 0)

2) Trivial, Continuous Self-Test alarm indications

Error Code	Description
Battery Failure	The secondary self tests detected battery self test has failed
Field Volt Fail	The secondary self tests detected Field Voltage failure

P1626ENa

Figure 15 - Continuous self-testing logic (P64x - P642/P643/P645 only)

COMMISSIONING

CHAPTER 10

Date:	02/2013
Hardware Suffix:	K
Software Version:	57/B0
Connection Diagrams:	10P44303 (SH 01 and 03) 10P44304 (SH 01 and 03) 10P44305 (SH 01 and 03) 10P44306 (SH 01 and 03) 10P44600 10P44601 (SH 1 to 2) 10P44602 (SH 1 to 2) 10P44603 (SH 1 to 2)

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1 INTRODUCTION

The MiCOM P443/P446 employs a high degree of self-checking and, in the unlikely event of a failure, will give an alarm. As a result of this, the commissioning tests do not need to be as extensive as with non-numeric electronic or electro-mechanical relays.

To commission numeric relays, it is only necessary to verify that the hardware is functioning correctly and the application-specific software settings have been applied to the relay. It is considered unnecessary to test every function of the relay if the settings have been verified by one of the following methods:

- Extracting the settings applied to the relay using appropriate setting software (preferred method)
- Via the operator interface

Unless previously agreed to the contrary, the customer will be responsible for determining the application-specific settings to be applied to the relay and for testing of any scheme logic applied by external wiring and/or configuration of the relay’s internal programmable scheme logic.

Blank commissioning test and setting records are provided at the end of this chapter for completion as required.

As the relay’s menu language is user-selectable, it is acceptable for the Commissioning Engineer to change it to allow accurate testing as long as the menu is restored to the customer’s preferred language on completion.

To simplify the specifying of menu cell locations in these Commissioning Instructions, they will be given in the form [courier reference: COLUMN HEADING, Cell Text]. For example, the cell for selecting the menu language (first cell under the column heading) is located in the System Data column (column 00) so it would be given as [0001: SYSTEM DATA, Language].

Caution **Before carrying out any work on the equipment, the user should be familiar with the contents of the Safety Guide (SFTY/4L M/C11) or later issue, or the Safety and Technical Data sections of this Technical Manual and also the ratings on the equipment’s rating label.**

Caution **The MiCOM P443/P446 relay must not be disassembled in any way during commissioning.**

2 COMMISSIONING TESTS - RELAY FACILITIES

To help minimize the time required to test MiCOM relays the relay provides several test facilities under the '**COMMISSION TESTS**' menu heading. There are menu cells which allow the status of the opto-isolated inputs, output relay contacts, internal digital data bus (DDB) signals and user-programmable LEDs to be monitored. Additionally there are cells to test the operation of the output contacts, user-programmable LEDs and, where available, the auto-reclose cycles.

The following table shows the relay menu of commissioning tests, including the available setting ranges and factory defaults:

Menu Text	Default Setting	DDB	Settings
COMMISSION TESTS			
Opto I/P Status			
Relay O/P Status			
Test Port Status			
LED Status			
Monitor Bit 1	1060: LED_CON_R1		0 to 1791 See Courier Database (P44y/EN GC) for details of digital data bus signals
Monitor Bit 2	1062: LED_CON_R2		
Monitor Bit 3	1064: LED_CON_R3		
Monitor Bit 4	1066: LED_CON_R4		
Monitor Bit 5	1068: LED_CON_R5		
Monitor Bit 6	1070 :LED_CON_R6		
Monitor Bit 7	1072: LED_CON_R7		
Monitor Bit 8	1074: LED_CON_R8		
Test Mode	Disabled		Disabled Test Mode Contacts Blocked
Test Pattern	All bits set to 0		0 = Not Operated 1 = Operated
Contact Test	No Operation		No Operation Apply Test Remove Test
Test LEDs	No Operation		No Operation Apply Test
Test Auto-reclose	No Operation		No Operation 3 Pole Test Pole A Test Pole B Test Pole C Test
Static Test	Disabled		Enabled Disabled
Loopback Mode	Disabled		Disabled Internal External
IM64 Test Pattern	All bits set to 0		0 = Not Operated 1 = Operated
IM64 Test Mode	Disabled		Disabled or Enabled

2.1 Opto I/P Status

This menu cell displays the status of the relay's opto-isolated inputs as a binary string, a '**1**' indicating an energized opto-isolated input and a '**0**' a de-energized one. If the cursor is moved along the binary numbers the corresponding label text will be displayed for each logic input.

It can be used during commissioning or routine testing to monitor the status of the opto-isolated inputs whilst they are sequentially energized with a suitable dc voltage.

2.2 Relay O/P Status

This menu cell displays the status of the digital data bus (DDB) signals that result in energization of the output relays as a binary string, a '**1**' indicating an operated state and '**0**' a non-operated state. If the cursor is moved along the binary numbers the corresponding label text will be displayed for each relay output.

The information displayed can be used during commissioning or routine testing to indicate the status of the output relays when the relay is '**in service**'. Additionally fault finding for output relay damage can be performed by comparing the status of the output contact under investigation with its associated bit.

Note *When the '**Test Mode**' cell is set to '**Contacts Blocked**' this cell will continue to indicate which contacts would operate if the relay was in-service, it does not show the actual status of the output relays.*

2.3 Test Port Status

This menu cell displays the status of the eight digital data bus (DDB) signals that have been allocated in the '**Monitor Bit**' cells. If the cursor is moved along the binary numbers the corresponding DDB signal text string will be displayed for each monitor bit.

By using this cell with suitable monitor bit settings, the state of the DDB signals can be displayed as various operating conditions or sequences are applied to the relay. Thus the programmable scheme logic can be tested.

2.4 Red LED Status and Green LED Status

The '**Red LED Status**' and '**Green LED Status**' cells are eighteen bit binary strings that indicate which of the user-programmable LEDs on the relay are illuminated when accessing the relay from a remote location, a '**1**' indicating a particular LED is lit and a '**0**' not lit. When the status of a particular LED in both cells is '**1**', this indicates the LEDs illumination is yellow.

2.5 Monitor Bits 1 to 8

The eight '**Monitor Bit**' cells allow the user to select the status of which digital data bus signals can be observed in the '**Test Port Status**' cell or via the monitor/download port. Each '**Monitor Bit**' is set by entering the required digital data bus (DDB) signal number (0 - 1791) from the list of available DDB signals in the Courier Database (P44y/EN GC). The pins of the monitor/download port used for monitor bits are given in the table overleaf. The signal ground is available on pins 18, 19, 22 and 25.

Monitor Bit	1	2	3	4	5	6	7	8
Monitor/Download Port Pin	11	12	15	13	20	21	23	24

Warning	**THE MONITOR/DOWNLOAD PORT DOES NOT HAVE ELECTRICAL ISOLATED AGAINST INDUCED VOLTAGES ON THE COMMUNICATIONS CHANNEL. IT SHOULD THEREFORE ONLY BE USED FOR LOCAL COMMUNICATIONS.**

2.6 Test Mode

This menu cell is to allow secondary injection testing to be performed on the relay. It also enables a facility to directly test the output contacts by applying menu controlled test signals. To select test mode the option ‘**Test Mode**’ should be selected. This takes the relay out of service causing an alarm condition to be recorded and the yellow ‘**Out of Service**’ LED to illuminate. This also freezes any information stored in the CB CONDITION column and, in IEC60870-5-103 versions, changes the Cause of Transmission, COT, to Test Mode. However the output contacts are still active in this mode. To disable the output contacts in addition to the above select ‘**Blocked**’. Once testing is complete the cell must be set back to ‘**Disabled**’ to restore the relay back to service. Test mode can also be selected by energizing an opto mapped to the Test Mode signal.

Warning	**WHEN THE ‘TEST MODE’ CELL IS SET TO ‘BLOCKED’ THE RELAY SCHEME LOGIC DOES NOT DRIVE THE OUTPUT RELAYS AND HENCE THE PROTECTION WILL NOT TRIP THE ASSOCIATED CIRCUIT BREAKER IF A FAULT OCCURS.**

2.7 Test Pattern

The ‘**Test Pattern**’ cell is used to select the output relay contacts that will be tested when the ‘**Contact Test**’ cell is set to ‘**Apply Test**’. The cell has a binary string with one bit for each user-configurable output contact which can be set to ‘**1**’ to operate the output under test conditions and ‘**0**’ to not operate it.

2.8 Contact Test

When the ‘**Apply Test**’ command in this cell is issued the contacts set for operation (set to ‘**1**’) in the ‘**Test Pattern**’ cell change state. After the test has been applied the command text on the LCD will change to ‘**No Operation**’ and the contacts will remain in the Test State until reset issuing the ‘**Remove Test**’ command. The command text on the LCD will again revert to ‘**No Operation**’ after the ‘**Remove Test**’ command has been issued.

Note	*When the ‘**Test Mode**’ cell is set to ‘**Contacts Blocked**’ the ‘**Relay O/P Status**’ cell does not show the current status of the output relays and hence can not be used to confirm operation of the output relays. Therefore it will be necessary to monitor the state of each contact in turn.*

2.9 Test LEDs

When the ‘**Apply Test**’ command in this cell is issued the eighteen user-programmable LEDs will illuminate yellow for approximately 2 seconds before they extinguish and the command text on the LCD reverts to ‘**No Operation**’.

2.10 Test Auto-Reclose

Where the relay provides an auto-reclose function, this cell will be available for testing the sequence of circuit breaker trip and auto-reclose cycles with the settings applied.

Issuing the command ‘**3 Pole Trip**’ will cause the relay to perform the first three phase trip/reclose cycle so that associated output contacts can be checked for operation at the correct times during the cycle. Once the trip output has operated the command text will revert to ‘**No Operation**’ whilst the rest of the auto-reclose cycle is performed. To test subsequent three phase auto-reclose cycles repeat the ‘**3 Pole Trip**’ command.

Similarly, where single pole auto-reclosing is available, the cycles for each single pole can be checked by sequentially issuing the ‘**Pole A Test**’, ‘**Pole B Test**’ or ‘**Pole C Test**’, as appropriate.

Note *The default settings for the relay’s programmable scheme logic has the ‘AR Trip Test’ signals mapped to the ‘Trip Input’ signals as shown in Figure 1 (P443 software version 54) and Figure 2 (P446 software version 55). If the programmable scheme logic has been changed, it is essential that these signals retain this mapping for the ‘Test Auto-reclose’ facility to work.*

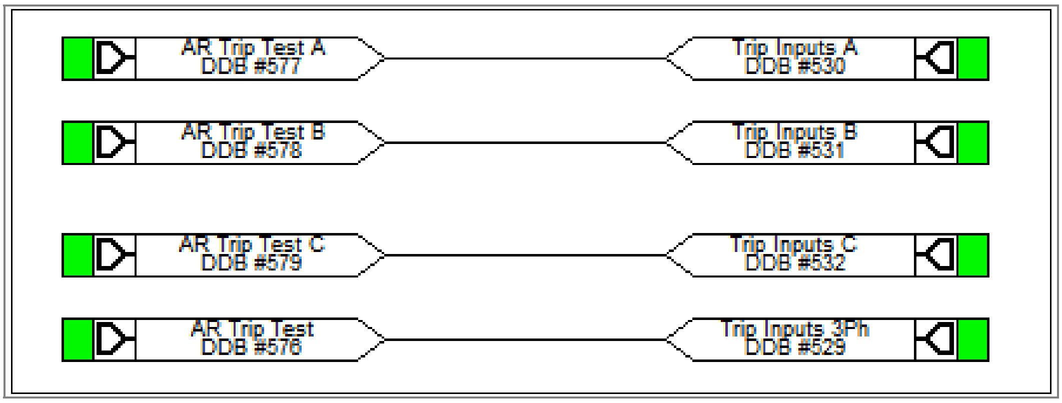
AR Trip Test A
DDB #577
Trip Inputs A
DDB #530
AR Trip Test B
DDB #578
Trip Inputs B
DDB #531
AR Trip Test C
DDB #579
Trip Inputs C
DDB #532
AR Trip Test
DDB #576
Trip Inputs 3Ph
DDB #529

Figure 1 - P443 auto-reclose default PSL

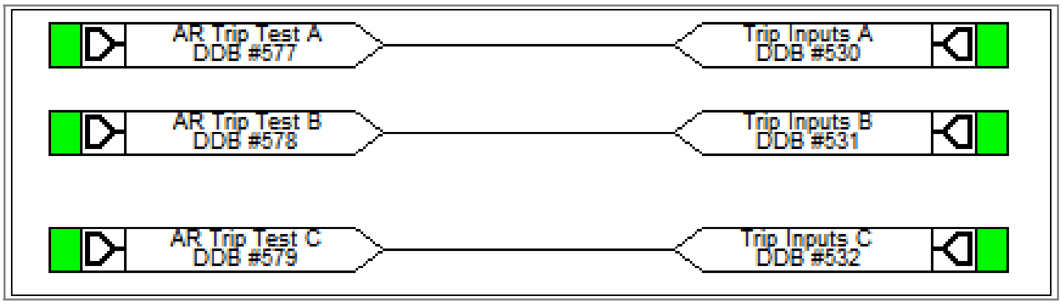
AR Trip Test A
DDB #577
Trip Inputs A
DDB #530
AR Trip Test B
DDB #578
Trip Inputs B
DDB #531
AR Trip Test C
DDB #579
Trip Inputs C
DDB #532

Figure 2 - P446 auto-reclose default PSL

2.11 Static Test Mode

Modern dynamic secondary injection test sets are able to accurately mimic real power system faults. The test sets mimic an instantaneous fault “**shot**”, with the real rate of rise of current, and any decaying DC exponential component, according to the point on (voltage) wave of fault inception. Injections for all three phases provide a six signal set of analog inputs: Va, Vb, Vc, Ia, Ib, Ic. Such injection test sets can be used with the P443/P446, with no special testing limitations.

- Conversely, older test sets may not properly simulate:
- A healthy prefault voltage memory
- A real fault shot (instead a gradually varying current or voltage may be used)
- The rate of rise of current and DC components
- A six signal set of analog inputs (instead, these may offer for example: Va, Vb, Ia, Ib only, to test for an A-B injection)

Such injection sets may be referred to as *“**Static**”* simulators.

As the P443/P446 relies on voltage memories and delta step changes as would happen on a real power system, certain functions within the relay must be disabled or bypassed to allow injection testing. Selecting the “**Static Mode**” test option serves to bypass the delta phase selectors, and power swing detection.

For the tests, the delta directional line is also replaced by a conventional distance directional line, and the digital filtering slows to use a fixed one cycle window. Memory polarizing is replaced by cross-polarizing from unfaulted phases.

The Static Test mode allows older injection test sets to be retained, and used to commission and test the P443/P446.

Note	Trip times may be up to ½ cycle longer when tested in the static mode, due to the nature of the test voltage and current, and the slower filtering. This is normal, and perfectly acceptable.

2.12 InterMiCOM Loopback Mode

The loopback test facilities provide the user with the ability to check the operation of the local InterMiCOM signaling (if fitted). This enables verification of the wiring between the relay communications port and any communications converter units prior to commissioning of the communications channel.

InterMiCOM exists in two different forms on the MiCOM relay. One version is presented on an electrical (EIA(RS)232) interface, designed primarily for use with modems, and is referred to as EIA(RS)232 InterMiCOM or MODEM InterMiCOM. The other uses faster signaling speeds, is presented on an optical fiber interface as is referred to as fiber InterMiCOM or InterMiCOM^{64}.

EIA(RS)232 InterMiCOM presents 8 command signaling bits over one communications channel. Fiber InterMiCOM^{64} presents 8 command signaling bits on one or two communications channels according to the application.

A test mode and test pattern facility is provided to help with testing. The functionality of these features differs subtly in the two forms of InterMiCOM and is explained below.

2.12.1 EIA(RS)232 InterMiCOM Loopback

The Loopback Mode setting for EIA(RS)232 InterMiCOM is found in the INTERMICOM COMMS column of the menu.

Note *By selecting the [1550 Loopback Mode] to “**Internal**” only the internal software of the relay is checked, and is useful for testing functionality if no communications connections are made, whereas “**External**” will check both the software and hardware used by InterMiCOM and is the preferred option during commissioning. When relay is switched into either ‘**Loopback Mode**’ the relay will automatically use generic addresses and will inhibit the InterMiCOM messages to the PSL by setting all eight InterMiCOM message command states to zero.*

2.12.2 Fiber InterMiCOM^{64} Loopback

The Test Loopback setting for the InterMiCOM^{64} is found in the COMMISSION TESTS column of the menu.

Note *By selecting the [0F13 Test Loopback] to “**Internal**” only the internal software of the relay is checked, and is useful for testing functionality if no communications connections are made, whereas “**External**” will check both the software and hardware and is the preferred option during commissioning. When the relay is switched into either ‘**Loopback Mode**’, the relay will automatically use generic addresses (address 0-0) and will respond as if it is connected to a remote relay. The signals sent and received over the InterMiCOM^{64} channel continue to be routed to and from the signals defined in the programmable logic.*

2.13 InterMiCOM Test Pattern

Test patterns can be set to confirm transmission of commands by the InterMiCOM channels and to exercise any associated logic. For EIA(RS)232 InterMiCOM the test pattern cell is found in the INTERMICOM COMMS column of the menu software. For the fiber InterMiCOM^{64}, the test pattern is found in the COMMISSION TESTS column of the menu.

2.13.1 EIA(RS)232 InterMiCOM Test Pattern

When the Loopback Mode setting for EIA(RS)232 InterMiCOM [1550 Loopback Mode] is set to “**Internal**” or “**External**”, all 8 InterMiCOM commands input to the PSL [1501 IM Input status] are set to zero. The InterMiCOM test pattern [1551 Test Pattern] can be used to test any of the 8 individual bits in the InterMiCOM messages by setting them to one and checking for correct reception in the [1502 IM Output status] register.

2.13.2 Fiber InterMiCOM^{64} Test Pattern

The [0F14 IM64Test Pattern] cell is used in conjunction with the [IM64 Test Mode] cell to set a 16-bit pattern (8 bits per channel) that is transmitted by the InterMiCOM^{64} message whilst ever the ‘**IM64 Test Mode**’ cell is set to ‘**Enable**’. The ‘**IM64 Test Pattern**’ cell has a binary string with one bit for each User Defined Inter-Relay Commands which can be set to ‘**1**’ to operate the IM64 output under test conditions and ‘**0**’ to not operate it.

2.13.3 Fiber InterMiCOM^{64} Test Mode

When the ‘**Enable**” command in this cell [0F15] is issued, the InterMiCOM^{64} commands change to reflect the state to the values set in the ‘**IM64 Test Pattern**’ cell. If set to ‘**Disable**’, the InterMiCOM^{64} commands reflect the state of the signals generated by the protection and control functionality of the relay.

2.14 Using a Monitor/Download Port Test Box

A monitor/download port test box containing 8 LED's and a switchable audible indicator is available. It is housed in a small plastic box with a 25-pin male D-connector that plugs directly into the relay's monitor/download port. There is also a 25-pin female D-connector which allows other connections to be made to the monitor/download port whilst the monitor/download port test box is in place.

Each LED corresponds to one of the monitor bit pins on the monitor/download port with '**Monitor Bit 1**' being on the left hand side when viewing from the front of the relay. The audible indicator can either be selected to sound if a voltage appears any of the eight monitor pins or remain silent so that indication of state is by LED alone.

3 SETTING FAMILIARIZATION

When commissioning a relay MiCOM P443/P446 for the first time, sufficient time should be allowed to become familiar with the method by which the settings are applied.

The Introduction (P44y/EN GS) contains a detailed description of the menu structure of P443/P446 relays.

With the secondary front cover in place all keys except the ⏎ key are accessible. All menu cells can be read. LEDs and alarms can be reset. However, no protection or configuration settings can be changed, or fault and event records cleared.

Removing the secondary front cover allows access to all keys so that settings can be changed, LEDs and alarms reset, and fault and event records cleared. However, menu cells that have access levels higher than the default level will require the appropriate password to be entered before changes can be made.

Alternatively, if a portable PC is available together with suitable setting software (such as MiCOM S1), the menu can be viewed a page at a time to display a full column of data and text. This PC software also allows settings to be entered more easily, saved to a file on disk for future reference or printed to produce a setting record. Refer to the PC software user manual for details. If the software is being used for the first time, allow sufficient time to become familiar with its operation.

4 EQUIPMENT REQUIRED FOR COMMISSIONING

4.1 Minimum Equipment Required

- Multifunctional dynamic current and voltage injection test set.
- Multimeter with suitable ac current range, and ac and dc voltage ranges of 0 - 440V and 0 - 250V respectively.
- Continuity tester (if not included in multimeter).
- Phase angle meter.
- Phase rotation meter.

Note *Modern test equipment may contain many of the above features in one unit.*

4.2 Optional Equipment

- Multi-finger test plug type P992 (if test block type P991 installed) or MMLB (if using MMLG blocks).
- An electronic or brushless insulation tester with a dc output not exceeding 500V (for insulation resistance testing when required).
- A portable PC, with appropriate software (this enables the rear communications port to be tested, if this is to be used, and will also save considerable time during commissioning).
- KITZ K-Bus to EIA(RS)232 protocol converter (if EIA(RS)485 K-Bus port is being tested and one is not already installed).
- EIA(RS)485 to EIA(RS)232 converter (if EIA(RS)485 MODBUS port is being tested).
- A printer (for printing a setting record from the portable PC).
- A fiber optic power meter and appropriate fiber optic test leads (InterMiCOM^{64} only).

5 PRODUCT CHECKS

These product checks cover all aspects of the relay which should be checked to ensure that it has not been physically damaged prior to commissioning, is functioning correctly and all input quantity measurements are within the stated tolerances.

If the application-specific settings have been applied to the relay prior to commissioning, it is advisable to make a copy of the settings so as to allow their restoration later. This could be done by:

- Obtaining a setting file on a diskette from the customer (this requires a portable PC with appropriate setting software for transferring the settings from the PC to the relay)
- Extracting the settings from the relay itself (this again requires a portable PC with appropriate setting software)
- Manually creating a setting record. This could be done using a copy of the setting record located at the end of this chapter to record the settings as the relay’s menu is sequentially stepped through via the front panel user interface

If password protection is enabled and the customer has changed password 2 that prevents unauthorized changes to some of the settings, either the revised password 2 should be provided, or the customer should restore the original password prior to commencement of testing.

Note *In the event that the password has been lost, a recovery password can be obtained from Schneider Electric by quoting the serial number of the relay. The recovery password is unique to that relay and is unlikely to work on any other relay.*

5.1 With the Relay De-Energized

Warning **The following group of tests should be carried out without the auxiliary supply being applied to the relay and with the trip circuit isolated.**

The current and voltage transformer connections must be isolated from the relay for these checks. If a P991 test block is provided, the required isolation can easily be achieved by inserting test plug type P992 that effectively open-circuits all wiring routed through the test block.

Before inserting the test plug, reference should be made to the scheme (wiring) diagram to ensure that this will not potentially cause damage or a safety hazard. For example, the test block may be associated with protection current transformer circuits. It is essential that the sockets in the test plug, which correspond to the current transformer secondary windings, are linked before the test plug is inserted into the test block.

Danger **Never open circuit the secondary circuit of a current transformer since the high voltage produced may be lethal and could damage insulation.**

If a test block is not provided, the voltage transformer supply to the relay should be isolated by means of the panel links or connecting blocks. The line current transformers should be short-circuited and disconnected from the relay terminals. Where means of isolating the auxiliary supply and trip circuit (e.g. isolation links, fuses, MCB, etc.) are provided, these should be used. If this is not possible, the wiring to these circuits will have to be disconnected and the exposed ends suitably terminated to prevent them from being a safety hazard.

5.1.1 Visual Inspection

Caution **The rating information given under the top access cover on the front of the relay should be checked. Check that the relay being tested is correct for the protected line/circuit. Ensure that the circuit reference and system details are entered onto the setting record sheet. Double-check the CT secondary current rating, and be sure to record the actual CT tap which is in use.**

Carefully examine the relay to see that no physical damage has occurred since installation.

Ensure that the case earthing connections, bottom left-hand corner at the rear of the relay case, are used to connect the relay to a local earth bar using an adequate conductor.

5.1.2 Current Transformer Shorting Contacts (Optional Check)

If required, the current transformer shorting contacts can be checked to ensure that they close when the heavy duty terminal block (block reference C in Figure 3) is disconnected from the current input PCB.

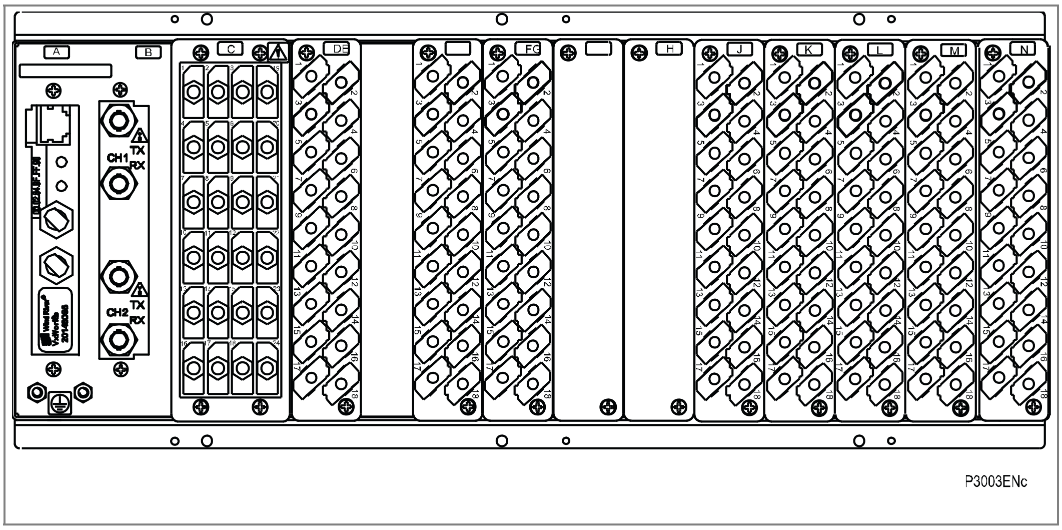

Figure 3 - Rear terminal blocks on size 80TE case

The heavy duty terminal block is fastened to the rear panel using four crosshead screws. These are located top and bottom between the first and second, and third and fourth, columns of terminals (see Figure 3).

Note *The use of a magnetic bladed screwdriver is recommended to minimize the risk of the screws being left in the terminal block or lost.*

Pull the terminal block away from the rear of the case and check with a continuity tester that all the shorting switches being used are closed. Table 1 shows the terminals between which shorting contacts are fitted.

Current Input	Shorting Contact Between Terminals	
	MiCOM P443 1A - Common - 5A	MiCOM P446 1A - Common - 5A
I_A	C3 - C2 - C1	D3 - D2 - D1
I_B	C6 - C5 - C4	D6 - D5 - D4
I_C	C9 - C8 - C7	D9 - D8 - D7
I_M	C12 - C11 - C10	D12 - D11 - D10
I_{SEF}	C15 - C14 - C13	D15 - D14 - D13
I_{A2}	N/A	F3 - F2 - F1
I_{B2}	N/A	F6 - F5 - F4
I_{C2}	N/A	F9 - F8 - F7

Table 1 - Current transformer shorting contact locations

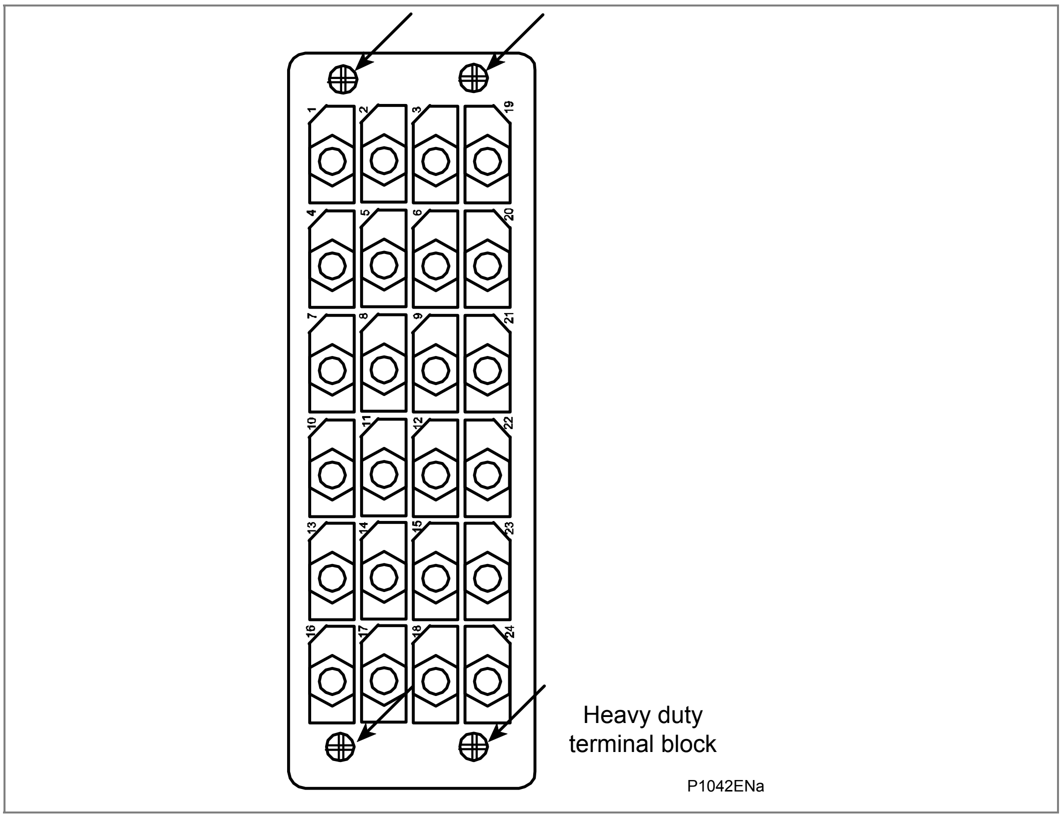

Figure 4 - Location of securing screws for heavy duty terminal blocks

5.1.3 Insulation

Insulation resistance tests are only necessary during commissioning if it is required for them to be done and they have not been performed during installation.

Isolate all wiring from the earth and test the insulation with an electronic or brushless insulation tester at a dc voltage not exceeding 500V. Terminals of the same circuits should be temporarily connected together.

The main groups of relay terminals are:

a. Voltage transformer circuits

b. Current transformer circuits

c. Auxiliary voltage supply

d. Field voltage output and opto-isolated control inputs

e. Relay contacts

f. EIA(RS)485 communication port

g. Case earth

The insulation resistance should be greater than 100MΩ at 500V.

On completion of the insulation resistance tests, ensure all external wiring is correctly reconnected to the relay.

5.1.4 External Wiring

Warning **Check that the external wiring is correct to the relevant relay diagram and scheme diagram. Ensure as far as practical that phasing/phase rotation appears to be as expected. The relay diagram number appears on the rating label under the top access cover on the front of the relay.**

If a P991 test block is provided, the connections should be checked against the scheme (wiring) diagram. It is recommended that the supply connections are to the live side of the test block colored orange with the odd numbered terminals (1, 3, 5, 7 etc.). The auxiliary supply is normally routed via terminals 13 (supply positive) and 15 (supply negative), with terminals 14 and 16 connected to the relay's positive and negative auxiliary supply terminals respectively. However, check the wiring against the schematic diagram for the installation to ensure compliance with the customer's normal practice.

5.1.5 Watchdog Contacts

Using a continuity tester, check that the watchdog contacts are in the states given in Table 2 for a de-energized relay.

Terminals		Contact State	
		Relay De-energized	Relay Energized
N11 - N12	P443	Closed	Open
N13 - N14	P443	Open	Closed
M11 - M12	P446	Closed	Open
M13 - M14	P446	Open	Closed

Table 2 - Watchdog contact status

5.1.6 Auxiliary Supply

The relay can be operated from either a dc only or AC/DC auxiliary supply depending on the relay's nominal supply rating. The incoming voltage must be within the operating range specified in Table 3.

Without energizing the relay measure the auxiliary supply to ensure it is within the operating range.

Nominal Supply Rating DC [AC rms]		DC Operating Range	AC Operating Range
24 - 48V	[-]	19 to 65V	-
48 - 110V	[40 - 100V]	37 to 150V	32 - 110V
110 - 250V	[100 - 240V]	87 to 300V	80 to 265V

Table 3 - Operational range of auxiliary supply Vx

It should be noted that the relay can withstand an ac ripple of up to 12% of the upper rated voltage on the dc auxiliary supply.

Warning **Do not energize the relay or interface unit using the battery charger with the battery disconnected as this can irreparably damage the relay's power supply circuitry.**

Energize the relay only if the auxiliary supply is within the specified operating ranges. If a test block is provided, it may be necessary to link across the front of the test plug to connect the auxiliary supply to the relay.

5.2 With the Relay Energized

Warning **The following group of tests verifies that the relay hardware and software is functioning correctly and should be carried out with the auxiliary supply applied to the relay.**

The current and voltage transformer connections must remain isolated from the relay for these checks. The trip circuit should also remain isolated to prevent accidental operation of the associated circuit breaker. The InterMiCOM or InterMiCOM^{64} communication channel (where fitted) should be disconnected to prevent the remote end relay being affected during the tests.

5.2.1 Watchdog Contacts

Using a continuity tester, check the watchdog contacts are in the states given in Table 2 for an energized relay.

5.2.2 LCD Front Panel Display

The liquid crystal display is designed to operate in a wide range of substation ambient temperatures. For this purpose, the Px40 relays have an "***LCD Contrast***" setting. This allows the user to adjust how light or dark the characters displayed will be. The contrast is factory pre-set to account for a standard room temperature; however it may be necessary to adjust the contrast to give the best in-service display. To change the contrast, cell [09FF: LCD Contrast] at the bottom of the CONFIGURATION column can be incremented (darker) or decremented (lighter), as required.

Care *Before applying a contrast setting, ensure that it will not render the display too light or dark such that menu text becomes unreadable. Should such a mistake be made, it is possible to restore a visible display by downloading a MiCOM S1 setting file, with the LCD Contrast set within the typical range of 7 - 11.*

5.2.3 Date and Time

Before setting the date and time, ensure that the factory-fitted battery isolation strip, that prevents battery drain during transportation and storage, has been removed. With the lower access cover open, presence of the battery isolation strip can be checked by a red tab protruding from the positive side of the battery compartment. Whilst lightly pressing the battery, to prevent it from falling out of the battery compartment, pull the red tab to remove the isolation strip.

The date and time should now be set to the correct values. The method of setting will depend on whether accuracy is being maintained via the optional Inter-Range Instrumentation Group standard B (IRIG-B) port on the rear of the relay.

5.2.3.1 With an IRIG-B Signal

If a satellite time clock signal conforming to IRIG-B is provided and the relay has the optional IRIG-B port fitted, the satellite clock equipment should be energized.

To allow the relay's time and date to be maintained from an external IRIG-B source cell [0804: DATE and TIME, IRIG-B Sync.] must be set to '**Enabled**'.

Ensure the relay is receiving the IRIG-B signal by checking that cell [0805: DATE and TIME, IRIG-B Status] reads '**Active**'.

Once the IRIG-B signal is active, adjust the time offset of the universal co-coordinated time (satellite clock time) on the satellite clock equipment so that local time is displayed.

Check the time, date and month are correct in cell [0801: DATE and TIME, Date/Time]. The IRIG-B signal does not contain the current year so it will need to be set manually in this cell.

In the event of the auxiliary supply failing, with a battery fitted in the compartment behind the bottom access cover, the time and date will be maintained. Therefore, when the auxiliary supply is restored, the time and date will be correct and not need to be set again.

To test this, remove the IRIG-B signal, and then remove the auxiliary supply from the relay. Leave the relay de-energized for approximately 30 seconds. On re-energization, the time in cell [0801: DATE and TIME, Date/Time] should be correct.

Reconnect the IRIG-B signal.

5.2.3.2 Without an IRIG-B Signal

If the time and date is not being maintained by an IRIG-B signal, ensure that cell

[0804: DATE and TIME, IRIG-B Sync.] is set to '**Disabled**'.

Set the date and time to the correct local time and date using cell [0801: DATE and TIME, Date/Time].

In the event of the auxiliary supply failing, with a battery fitted in the compartment behind the bottom access cover, the time and date will be maintained. Therefore when the auxiliary supply is restored the time and date will be correct and not need to be set again.

To test this, remove the auxiliary supply from the relay for approximately 30 seconds. On re-energization, the time in cell [0801: DATE and TIME, Date/Time] should be correct.

5.2.4 Light Emitting Diodes (LEDs)

On power up the green LED should have illuminated and stayed on indicating that the relay is healthy. The relay has non-volatile memory which remembers the state (on or off) of the alarm, trip and, if configured to latch, user-programmable LED indicators when the relay was last energized from an auxiliary supply. Therefore these indicators may also illuminate when the auxiliary supply is applied.

If any of these LEDs are on then they should be reset before proceeding with further testing. If the LEDs successfully reset (the LED goes out), there is no testing required for that LED because it is known to be operational.

Note	*It is likely that alarms related to the communications channels will not reset at this stage.*

5.2.4.1 Testing the Alarm and Out of Service LEDs

The alarm and out of service LEDs can be tested using the COMMISSION TESTS menu column. Set cell [0F0D: COMMISSION TESTS, Test Mode] to ‘**Contacts Blocked**’. Check that the out of service LED illuminates continuously and the alarm LED flashes.

It is not necessary to return cell [0F0D: COMMISSION TESTS, Test Mode] to ‘**Disabled**’ at this stage because the test mode will be required for later tests.

5.2.4.2 Testing the Trip LED

The trip LED can be tested by initiating a manual circuit breaker trip from the relay. However, the trip LED will operate during the setting checks performed later. Therefore no further testing of the trip LED is required at this stage.

5.2.4.3 Testing the User-Programmable LEDs

To test the user-programmable LEDs set cell [0F10: COMMISSION TESTS, Test LEDs] to ‘**Apply Test**’. Check that all 18 LED’s on the right-hand side of the relay illuminate yellow for approximately 2 seconds.

5.2.5 Field Voltage Supply

The relay generates a field voltage of nominally 48V that can be used to energize the opto-isolated inputs (alternatively the substation battery may be used).

Measure the field voltage voltage across the terminals 7 and 9 on the terminal block given in Table 4. Check that the field voltage is within the range 40V to 60V when no load is connected and that the polarity is correct.

Repeat for terminals 8 and 10.

Supply Rail	Terminals	
	P443	P446
+ve	N7 & N8	M7 & M8
–ve	N9 & N10	M9 & M10

Table 4 - Field voltage terminals

5.2.6 Input Opto-Isolators

This test checks that all the opto-isolated inputs on the relay are functioning correctly.

- The P443 with I/O options “**A**” and “**C**” (model no. begins: P443xxx**A**..or P443xxx**C**..) has 16 opto inputs
- The P443 with I/O options “**B**” and “**D**” (model no. begins: P443xxx**B**..or P443xxx**D**..) has 24 opto inputs
- The P446 always has 24 opto inputs

The opto-isolated inputs should be energized one at a time, see external connection diagrams (P44y/EN IN) for terminal numbers. Ensuring correct polarity, connect the field supply voltage to the appropriate terminals for the input being tested.

Note	*The opto-isolated inputs may be energized from an eternal dc auxiliary supply (e.g. the station battery) in some installations. Check that this is not the case before connecting the field voltage otherwise damage to the relay may result.*

The status of each opto-isolated input can be viewed using either cell [0020: SYSTEM DATA, Opto I/P Status] or [0F01: COMMISSION TESTS, Opto I/P Status], a ‘**1**’ indicating an energized input and a '**0**' indicating a de-energized input. When each opto-isolated input is energized one of the characters on the bottom line of the display will change to indicate the new state of the inputs.

5.2.7 Output Relays

This test checks that all the output relays are functioning correctly.

- P443 option "**A**" (model no. begins: P443xxxA..) has 24 relay outputs
- P443 option "**B**" (model no. begins: P443xxxB..) has 32 relay outputs
- P443 option "**C**" (model no. begins: P443xxxC..) has 16 standard relay outputs and 4 high break relay outputs.
- P443 option "**D**" (model no. begins: P443xxxD..) has 16 standard relay outputs and 8 high break relay outputs.
- P446 option "**A**" (model no. begins: P446xxxA..) has 32 relay outputs
- P446 option "**B**" (model no. begins: P443xxxB..) has 8 standard relay outputs and 12 high break relay outputs.
- P446 option "**C**" (model no. begins: P443xxxC..) has 16 standard relay outputs and 8 high break relay outputs.

Note	*The high break output contacts fitted to I/O options "**C**" and "**D**" are polarity sensitive. External wiring should, wherever possible, be verified against polarity requirements described in the external connection diagram (10P4430x/10P4460x) to ensure correct high break operation when in service.*

Ensure that the relay is still in test mode by viewing cell [0F0D: COMMISSION TESTS, Test Mode] to ensure that it is set to '**Blocked**'.

The output relays should be energized one at a time. To select output relay 1 for testing, set cell [0F0E: COMMISSION TESTS, Test Pattern] as appropriate.

Connect a continuity tester across the terminals corresponding to output relay 1 as given in external connection diagram (P44y/EN IN).

To operate the output relay set cell [0F0F: COMMISSION TESTS, Contact Test] to '**Apply Test**'. Operation will be confirmed by the continuity tester operating for a normally open contact and ceasing to operate for a normally closed contact. Measure the resistance of the contacts in the closed state.

Reset the output relay by setting cell [0F0F: COMMISSION TESTS, Contact Test] to '**Remove Test**'.

Note	*It should be ensured that thermal ratings of anything connected to the output relays during the contact test procedure are not exceeded by the associated output relay being operated for too long. It is therefore advised that the time between application and removal of the contact test is kept to the minimum.*

Repeat the test for the remaining relays.

Return the relay to service by setting cell [0F0D: COMMISSION TESTS, Test Mode] to '**Disabled**'.

5.2.8 Rear Communications Port

This test should only be performed where the relay is to be accessed from a remote location and will vary depending on the communications standard being adopted.

It is not the intention of the test to verify the operation of the complete system from the relay to the remote location, just the relay's rear communications port and any protocol converter necessary.

5.2.8.1 Courier Communications

If a K-Bus to EIA(RS)232 KITZ protocol converter is installed, connect a portable PC running the appropriate software to the incoming (remote from relay) side of the protocol converter. The terminal numbers for the relay's K-Bus port are given in Table 5.

Connection		Terminal	
K-Bus	**IEC 60870-5-103 or DNP3.0**	**P443**	**P446**
Screen	Screen	N16	M16
1	+ve	N17	M17
2	–ve	N18	M18

Table 5 - EIA(RS)485 terminals

Ensure that the communications baud rate and parity settings in the application software are set the same as those on the protocol converter (usually a KITZ but could be a SCADA RTU). The relays courier address in cell [0E02: COMMUNICATIONS, Remote Access] must be set to a value between 1 and 254.

Check that communications can be established with this relay using the portable PC.

5.2.8.2 IEC60870-5-103 (VDEW) Communications

If the relay has the optional fiber optic communications port fitted, the port to be used should be selected by setting cell [0E07: COMMUNICATIONS, Physical Link] to '**Fiber Optic**'.

IEC60870-5-103/VDEW communication systems are designed to have a local Master Station and this should be used to verify that the relay's fiber optic or EIA(RS)485 port, as appropriate, is working.

Ensure that the relay address and baud rate settings in the application software are set the same as those in cell [0E04: COMMUNICATIONS, Baud Rate] of the relay.

Check that, using the Master Station, communications with the relay can be established.

5.2.8.3 DNP3.0 Interface

Connect a portable PC running the appropriate DNP3.0 software to the relay's EIA(RS)485 port via an EIA(RS)232 interface converter. The terminal numbers for the relay's EIA(RS)485 port are given in Table 5. Ensure that the relay address, baud rate and parity are set the same as those in cells [0E04: COMMUNICATIONS, Baud Rate] and [0E05: COMMUNICATIONS, Parity] of the relay.

Check that communications with this relay can be established.

5.2.9 Second Rear Communications Port

This test should only be performed where the relay is to be accessed from a remote location and will vary depending on the communications standard being adopted.

It is not the intention of the test to verify the operation of the complete system from the relay to the remote location, just the relays rear communications port and any protocol converter necessary.

5.2.9.1 K-Bus Configuration

If a K-Bus to EIA(RS)232 KITZ protocol converter is installed, connect a portable PC running the appropriate software (e.g. MiCOM S1 or PAS&T) to the incoming (remote from relay) side of the protocol converter.

If a KITZ protocol converter is not installed, it may not be possible to connect the PC to the relay installed. In this case a KITZ protocol converter and portable PC running appropriate software should be temporarily connected to the relays second rear communications port configured for K-Bus. The terminal numbers for the relays K-Bus port are given in Table 6. However, as the installed protocol converter is not being used in the test, only the correct operation of the relays K-Bus port will be confirmed.

Pin*	Connection
4	EIA(RS)485 - 1 (+ ve)
7	EIA(RS)485 - 2 (- ve)
* - All other pins unconnected.	

Table 6 - 2nd rear communications port K-Bus terminals

Ensure that the communications baud rate and parity settings in the application software are set the same as those on the protocol converter (usually a KITZ but could be a SCADA RTU). The relays courier address in cell [0E90: COMMUNICATIONS, RP2 Address] must be set to a value between 1 and 254. The second rear communications port configuration [0E88: COMMUNICATIONS RP2 Port Config.] must be set to K-Bus.

Check that communications can be established with this relay using the portable PC.

5.2.9.2 EIA(RS)485 Configuration

If an EIA(RS)485 to EIA(RS)232 converter (Schneider Electric CK222) is installed, connect a portable PC running the appropriate software (e.g. MiCOM S1) to the EIA(RS)232 side of the converter and the second rear communications port of the relay to the EIA(RS)485 side of the converter.

The terminal numbers for the relays EIA(RS)485 port are given in Table 6.

Ensure that the communications baud rate and parity settings in the application software are set the same as those in the relay. The relays courier address in cell [0E90: COMMUNICATIONS, RP2 Address] must be set to a value between 1 and 254. The second rear communications port configuration [0E88: COMMUNICATIONS RP2 Port Config.] must be set to EIA(RS)485.

Check that communications can be established with this relay using the portable PC.

5.2.9.3 EIA(RS)232 Configuration

Connect a portable PC running the appropriate software (e.g. MiCOM S1) to the rear EIA(RS)232 port of the relay. This rear port is actually compliant to EIA(RS)574; the 9-pin version of EIA(RS)232, see www.tiaonline.org

The second rear communications port connects via the 9-way female D-type connector (SK4). The connection is compliant to EIA(RS)574.

Pin	Connection
1	No Connection
2	RxD
3	TxD
4	DTR#
5	Ground
6	No Connection

Pin	Connection
7	RTS#
8	CTS#
9	No Connection
# - These pins are control lines for use with a modem.	

Table 7 - Second rear communications port EIA(RS)232 terminals

Connections to the second rear port configured for EIA(RS)232 operation can be made using a screened multi-core communication cable up to 15m long, or a total capacitance of 2500pF. The cable should be terminated at the relay end with a 9-way, metal shelled, D-type male plug. The terminal numbers for the relays EIA(RS)232 port are given in Table 7.

Ensure that the communications baud rate and parity settings in the application software are set the same as those in the relay. The relays courier address in cell [0E90: COMMUNICATIONS, RP2 Address] must be set to a value between 1 and 254. The second rear communications port configuration [0E88: COMMUNICATIONS RP2 Port Config.] must be set to EIA(RS)232.

Check that communications can be established with this relay using the portable PC.

5.2.10 Current Inputs

This verifies that the accuracy of current measurement is within the acceptable tolerances.

All relays will leave the factory set for operation at a system frequency of 50Hz.
If operation at 60Hz is required then this must be set in cell [0009: SYSTEM DATA, Frequency].

Apply current equal to the line current transformer secondary winding rating to each current transformer input of the corresponding rating in turn, see table 1 or external connection diagram (P44y/EN IN) for appropriate terminal numbers, checking its magnitude using a multimeter/test set readout. The corresponding reading can then be checked in the relay’s MEASUREMENTS 1 column and value displayed recorded.

The measured current values displayed on the relay LCD or a portable PC connected to the front communication port will either be in primary or secondary Amperes. If cell [0D02: MEASURE’T SETUP, Local Values] is set to ‘**Primary**’, the values displayed should be equal to the applied current multiplied by the corresponding current transformer ratio set in the ‘**CT and VT RATIOS**’ menu column (see Table 8). If cell [0D02: MEASURE’T SETUP, Local Values] is set to ‘**Secondary**’, the value displayed should be equal to the applied current.

Note	*If a PC connected to the relay via the rear communications port is being used to display the measured current, the process will be similar. However, the setting of cell [0D03: MEASURE’T SETUP, Remote Values] will determine whether the displayed values are in primary or secondary Amperes. The measurement accuracy of the relay is ±1%. However, an additional allowance must be made for the accuracy of the test equipment being used.*

Current Input	Shorting Contact Between Terminals	
	MiCOM P443 1A - Common - 5A	MiCOM P446 1A - Common - 5A
I_A	C3 - C2 - C1	D3 - D2 - D1
I_B	C6 - C5 - C4	D6 - D5 - D4
I_C	C9 - C8 - C7	D9 - D8 - D7

Current Input	Shorting Contact Between Terminals	
	MiCOM P443 1A - Common - 5A	**MiCOM P446 1A - Common - 5A**
I_M	C12 - C11 - C10	D12 - D11 - D10
I^{SEF}	C15 - C14 - C13	D15 - D14 - D13
I^{A2}	N/A	F3 - F2 - F1
I^{B2}	N/A	F6 - F5 - F4
I^{C2}	N/A	F9 - F8 - F7

Table 8 - Current transformer shorting contact locations

Cell in MEASUREMENTS 1 Column (02)	Corresponding CT Ratio (in 'CT and VT RATIOS' Column(0A) of Menu)
[0201: IA Magnitude] [0203: IB Magnitude [0205: IC Magnitude]	[0A07 : Phase CT Primary] [0A08 : Phase CT Secondary]
[0232: IM Magnitude]	[0A0D : Mcomp CT Primary] [0A0E : Mcomp CT Secondary]
[020B: ISEF Magnitude]	[0A0B : SEF amp CT Primary] [0A0C : SEF amp CT Secondary]

Table 9 - CT ratio settings

5.2.11 Voltage Inputs

This test verifies that the accuracy of voltage measurement is within the acceptable tolerances.

Apply rated voltage to each voltage transformer input in turn, checking its magnitude using a multimeter/test set readout. Refer to Table 10 for the corresponding reading in the relay's MEASUREMENTS 1 column and record the value displayed.

Cell in MEASUREMENTS 1 Column	Voltage Applied To	
	MiCOM P443	**MiCOM P446**
[021A: VAN Magnitude]	C19 - C22	D19 - D22
[021C: VBN Magnitude]	C20 - C22	D20 - D2
[021E: VCN Magnitude]	C21 - C22	D21 - D22
[022E: (CB1) CS Volt Mag]	C23 - C24	D23 - D24
[024C: CB2 CS Volt Mag]	N/A	D23 - D24

Table 10 - Voltage input terminals

The measured voltage values on the relay LCD or a portable PC connected to the front communication port will either be in primary or secondary volts. If cell [0D02: MEASURE'T SETUP, Local Values] is set to '**Primary**', the values displayed should be equal to the applied voltage multiplied by the corresponding voltage transformer ratio set in the '**VT and CT RATIOS**' menu column (see Table 10). If cell [0D02: MEASURE'T SETUP, Local Values] is set to '**Secondary**', the value displayed should be equal to the applied voltage.

Note *If a PC connected to the relay via the rear communications port is being used to display the measured voltage, the process will be similar. However, the setting of cell [0D03: MEASURE'T SETUP, Remote Values] will determine whether the displayed values are in primary or secondary Volts.*

The measurement accuracy of the relay is ±1%. However, an additional allowance must be made for the accuracy of the test equipment being used.

Cell in MEASUREMENTS 1 Column (02)	Corresponding CT Ratio (in 'CT and VT RATIOS' Column (0A) of Menu)
[021A: VAN Magnitude] [021C: VBN Magnitude] [021E: VCN Magnitude]	$\frac{\text{[0A01 : Main VT Primary]}}{\text{[0A02 : Main VT Secondary]}}$
[022E: (CB1) CS Volt Mag]	[0A03 : (CB1) CS VT Prim'y] [0A04 : (CB1) CS VT Sec'y]
[024C: CB2 CS Volt Mag] (P446 only)	[0A05 : CB2 CS VT Prim'y] [0A06 : CB2 CS VT Sec'y]

Table 11 - Voltage ratio settings

6 INTERMICOM COMMUNICATIONS LOOPBACK

If the MiCOM relay is being used in a scheme with InterMiCOM communications it will be necessary to configure a loopback on the InterMiCOM communications. If InterMiCOM is not being used, skip to section 7.

The loopback should be made as close as possible to where the communication link leaves the substation such that as much of the wiring as possible and all associated communication signal converters are included in the test.

InterMiCOM exists in two different forms on the MiCOM relay. One version is presented on an electrical (EIA(RS)232) interface and is referred to as EIA(RS)232 InterMiCOM or MODEM InterMiCOM; the other is presented on an optical fiber interface as is referred to as fiber InterMiCOM or InterMiCOM^{64}.

It is possible for a relay to have both MODEM InterMiCOM and InterMiCOM^{64} fitted, and both can be operational at the same time. If both are fitted, both should be tested even if one appears not to be used, since it may be that a future upgrade of communications services is envisaged that will see a migration from one implementation to the other. If only InterMiCOM^{64} is fitted, skip to section 6.2.

6.1 EIA(RS)232 InterMiCOM Communications

Using the relay menu structure, ensure that the InterMiCOM communications is enabled using the [0940 InterMiCOM] cell in the [09 CONFIGURATION] column.

Set the [1520 Ch Statistics] and [1540 Ch Diagnostics] cells to visible.

Check that the InterMiCOM hardware is fitted and initialized by checking that the [1545 IM HW Status] cell displays ‘**OK**’.

6.1.1 MODEM InterMiCOM Loopback Testing & Diagnostics

The MODEM InterMiCOM “**Loopback**” test facilities, located within the [15 INTERMICOM COMMS] column of the relay menu, provide a user with the ability to check the InterMiCOM signaling.

Note	*By selecting the [1550 Loopback Mode] to “**Internal**”, only the internal software of the relay is checked. This is useful for testing functionality if no communications connections are made, whereas “**External**” will check both the software and hardware used by InterMiCOM and is the preferred option during commissioning. When the relay is switched into either ‘**Loopback Mode**’ the relay will automatically use generic addresses and will inhibit the InterMiCOM messages to the PSL by setting all eight InterMiCOM message command states to zero.*

Set the [1550 Loopback Mode] cell to ‘**External**’ and form a communications loopback by connecting the transmit and receive signals together. In its simplest form, this is achieved by connecting the transmit and receive pins together (pins 2 and 3) as per Figure 4 below.

Note	*The DCD signal must be held high (connect pin 1 and pin 4 together) if any connected equipment does not support DCD. In practice, it is likely that some form of communications converter will have been employed (refer to the operations (OP) section of this manual for examples), and the loopback will not be at the InterMiCOM connector as it should be made as far into the communications channel as possible so that as much wiring as possible, and as many ancillary communication components (converters, associated power supplies, etc.) as possible are included in the test.*

The loopback mode will be indicated on the relay frontplate by the amber Alarm LED being illuminated and a LCD alarm message, "**IM Loopback**".

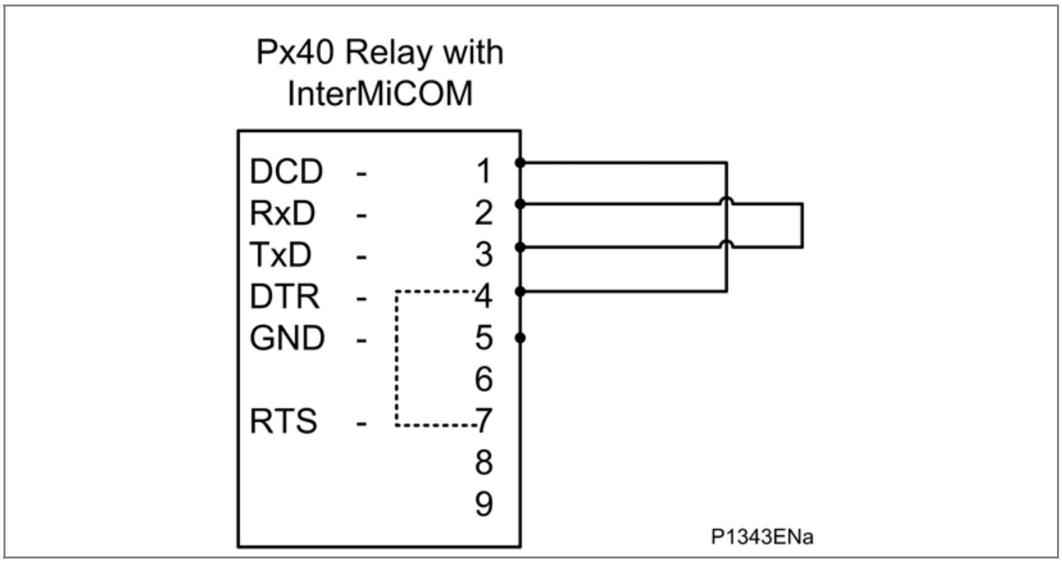

Figure 5 - Example connections for InterMiCOM communications loopback

Providing all connections are correct and the software is working correctly, observe that the [1552 Loopback Status] cell that is located within the INTERMICOM COMMS column of the relay menu displays "**OK**".

6.1.1.1 MODEM InterMiCOM Command Bits

To test the InterMiCOM command bits, enter any test pattern in the [1551 Test Pattern] cell by scrolling through and changing selected bits between "**1**" and "**0**". The entered pattern will be transmitted through the loopback. Check that the [1502 IM Output Status] cell matches with the applied '**Test Pattern**'. Also check that all 8 bits in the [1501 IM Input Status] cell are zero.

6.1.1.2 MODEM InterMiCOM Channel Diagnostics

Check that the Channel Diagnostics status is displaying:

[1541 Data CD Status]	OK
[1542 FrameSync Status]	OK
[1543 Message Status]	OK
[1544 Channel Status]	OK

6.1.1.3 MODEM InterMiCOM Channel Failure

Simulate a failure of the communications link by breaking a connection and checking that some of these cells indicate '**fail**'.

Note *Some or all of these cells will indicate '**fail**' according to the communications configuration and the manner in which the link has been failed.*

Restore the communications loopback and ensure that the four diagnostic cells display '**OK**'.

Unless InterMiCOM^{64} is also fitted, skip to section 7, otherwise, proceed with section 6.2.

6.2 InterMiCOM^{64} Fiber Communications

This test verifies that the relay's teleprotection fiber optic communications ports together with any associated P590 interface units are operating correctly.

A number of different fiber-optic interfaces are available for InterMiCOM^{64}. These are described in detail in the Operation (OP) and Application Notes (AP) sections of this manual. In general, 1300nm fiber optics (either single-mode or multi-mode) are used for direct fiber optic connections, and 850nm multi-mode fiber optic connections are employed in conjunction with multiplexing telecommunications equipment. It is important that any optical fibers used for testing are correct for the interface(s) specified. Optical fibers should be terminated with BFOC2.5 (ST2.5) connectors. For multi-mode applications the use of 50/125µm cored fiber is recommended. Any fiber-optic test leads used for measurements should be sufficiently long to assure mode stripping, and a minimum length of 10m (30ft) is recommended to achieve this.

A P590 unit will be situated near the multiplexer in applications where communications between P443/P446 relays is via multiplexed electrical communication channels and the PCM multiplexer is installed remote from the relay room. This unit provides bi-directional optical to electrical signal conversion between the cross-site optical fiber from the relay and the electrical interface of the multiplexer.

Using the relay menu structure, ensure that the InterMiCOM^{64} communications is enabled by setting the [0941 InterMiCOM^{64}] cell.

The method of testing is similar whether communications between relays is via dedicated optical fibers, using a P590 unit to interface the relay's fiber optic communications channel to a multiplexer, or direct fiber connection to a multiplexer supporting the IEEE C37.94 standard. However, where P590 interface units are being used, there are a number of extra tests on the P590 units that need to be performed refer to sections 6.2.4 (P591), 6.2.5 (P592), and 6.2.6 (P593) respectively. If the relay is to be connected to a multiplexer supporting the IEEE C37.94 standard, the loopback testing is performed exactly the same as for a direct fiber connection described in section 6.2.2.

Note *It is possible that two channels may have different implementations and the sections describing the commissioning of the interfaces and the loopback tests should be used as relevant to each channel.*

Warning **When connecting or disconnecting optical fibers care should be taken not to look directly into the transmit port or end of the optical fiber.**

6.2.1 Communications Loopback Setting

The loopback test can be used to establish correct operation of the local communication interface.

Note *In loopback mode the signals sent and received via the InterMiCOM^{64} interface continue to be routed to and from the signals defined in the programmable logic unless the IM64 Test Mode is set to 'Enabled' in which case the IM64 Test Pattern is transmitted.*

Set cell [0F13 Test Loopback] to '**External**'.

6.2.1.1 Channel 1 Transmit Power Level

Using an appropriate fiber optic cable, connect the Channel 1 Transmitter (TX1) to an optical power meter. Check that the average power transmitted is within the range given in the following tables:

Relays Manufactured Pre April 2008	850nm multi-mode	1300nm multi-mode	1300nm single-mode
Maximum Transmitter Power (Average Value)	-19.8dBm	-7dBm	-7dBm
Minimum Transmitter Power (Average Value)	-22.8dBm	-13dBm	-13dBm

Relays Manufactured Post April 2008	850nm multi-mode	1300nm multi-mode	1300nm single-mode
Maximum Transmitter Power (Average Value)	-19.8dBm	-3dBm	-3dBm
Minimum Transmitter Power (Average Value)	-22.8dBm	-9dBm	-9dBm

Record the transmit power level.

6.2.1.2 Channel 2 Transmit Power Level

Repeat section 6.2.1.1 for channel 2 (if fitted)

6.2.2 Loopback Communications Configuration

A communications loopback will need to be made on the InterMiCOM^{64} communications. Either one or two channels will be fitted according to specification. A combination of direct fiber connection or multiplexed (using P59x units) connection can be used on each of the channels. Sections 6.2.3 to 6.2.6 describe how the various loopback are made. They should be followed as appropriate to configure the loopback on channel 1 and the loopback on channel 2, before proceeding to the loopback test described in section 6.2.7.

If the communications is being realised using P590 interface units, then start by connecting the appropriate optical fiber(s) between the channel transmitter(s) on the MiCOM that will be used to make connection to the P590 optical receiver(s) and then proceed to the relevant sections below that describe the commissioning of the P590 interface units.

6.2.3 Fiber Connection

Where direct fiber connections are being used (or where multiplexer channels conforming to the IEEE C37.94 standard are being used), using an appropriate optical fiber cable, connect the channel transmitter to the channel receiver port on the rear of the relay.

6.2.4 Communications using P591 Interface Units (G.703)

6.2.4.1 P591 Visual Inspection

Carefully examine the unit to see that no physical damage has occurred since installation.

The rating information given under the top access cover on the front of the unit should be checked to ensure it is correct for the particular installation.

Ensure that the case earthing connection, top left-hand corner at the rear of the case, is used to connect the unit to a local earth bar using an adequate conductor.

6.2.4.2 P591 Insulation

Insulation resistance tests are only necessary during commissioning if it is required for them to be done and they haven’t been performed during installation.

Isolate all wiring from the earth and test the insulation with an electronic or brushless insulation tester at a dc voltage not exceeding 500V. The auxiliary dc supply terminals should be temporarily connected together.

The insulation resistance should be greater than 100MΩ at 500V.

On completion of the insulation resistance tests, ensure all external wiring is correctly reconnected to the P591.

6.2.4.3 P591 External Wiring

Check that the external wiring is correct to the relevant connection diagram or scheme diagram. The connection diagram number appears on the rating label under the top access cover on the front of the P591. The corresponding connection diagram will have been supplied with the Schneider Electric order acknowledgement for the P591.

Warning **It is especially important that the dc supplies are wired with the correct polarity.**

6.2.4.4 P591 Auxiliary Supply

P591 units operate from a dc only auxiliary supply within the operative range of 19V to 65V for a 24 - 48V version and 87.5V to 300V for a 110 - 250V version.

Without energizing the P591 units measure the auxiliary supply to ensure it is within the operating range.

It should be noted that the P591 interface unit is designed to withstand an ac ripple component of up to 12% of the normal dc auxiliary supply. However, in all cases the peak value of the dc supply must not exceed the maximum specified operating limit.

Warning **Do not energize the P591 using the battery charger with the battery disconnected as this can irreparably damage the unit’s power supply circuitry.**

6.2.4.5 P591 Light Emitting Diode (LED)

On power up the green ‘**SUPPLY HEALTHY**’ LED should have illuminated and stayed on, thus indicating that the P591 is healthy.

6.2.4.6 P591 Optical Received Signal Level

With an optical cable connected to the MiCOM optical transmitter as instructed in section 6.2.2, disconnect the other end of the cable from the P591 receiver (RX) and use an optical power meter to measure the received signal strength. The value should be in the range -16.8dBm to -25.4dBm. Record the measured value and replace the connector to the P591 receiver.

6.2.4.7 P591 Loopback

It is necessary to loop the transmitted electrical G.703 signal presented on terminals 3 and 4 of the P591 to the received signal presented on terminals 7 and 8. If test links have been designed into the scheme to facilitate this they should be used. Alternatively, remove any external wiring from terminals 3, 4, 7 and 8 at the rear of each P591 unit.

Loopback the G.703 signals on each unit by connecting a wire link between terminals 3 and 7, and a second wire between terminals 4 and 8.

6.2.4.8 P591 Optical Transmitter Signal Level

Using an appropriate fiber optic cable, connect the optical transmitter (TX) to an optical power meter. Check that the average power transmitted is within the range -16.8dBm to -22.8dBm.

Record the transmit power level.

Connect the appropriate optical fiber to connect the P591 transmitter to the MiCOM optical receiver and return to the MiCOM relay.

6.2.4.9 MiCOM Optical Received Signal Level from P591

Return to the MiCOM relay. Disconnect the fiber from the MiCOM optical receiver that connects to the optical transmitter of the P591 and measure the received signal level. The value should be in the range -16.8dBm to -25.4dBm. Record the measurement and then reconnect the fiber to the optical receiver.

6.2.5 Communications using P592 Interface Units (V.35)

Before loopback testing can begin, some other checks must be completed.

6.2.5.1 P592 Visual Inspection

Carefully examine the unit to see that no physical damage has occurred since installation.

The rating information given under the top access cover on the front of the unit should be checked to ensure it is correct for the particular installation.

Ensure that the case earthing connection, top left-hand corner at the rear of the case, is used to connect the unit to a local earth bar using an adequate conductor.

6.2.5.2 P592 Insulation

Insulation resistance tests are only necessary during commissioning if it is required for them to be done and they haven’t been performed during installation.

Isolate all wiring from the earth and test the insulation with an electronic or brushless insulation tester at a dc voltage not exceeding 500V. The auxiliary dc supply terminals should be temporarily connected together.

⚠ **Warning** **The V.35 circuits of the P592 are isolated from all other circuits but are electrically connected to the outer case. The circuits must not therefore be insulation or impulse tested to the case.**

The insulation resistance should be greater than 100MΩ at 500V.

On completion of the insulation resistance tests, ensure all external wiring is correctly reconnected to the P592.

6.2.5.3 P592 External Wiring

Check that the external wiring is correct to the relevant connection diagram or scheme diagram. The connection diagram number appears on the rating label under the top access cover on the front of the P592. The corresponding connection diagram will have been supplied with the Schneider Electric order acknowledgement for the P592.

Warning **It is especially important that the dc supplies are wired with the correct polarity.**

6.2.5.4

P592 Auxiliary Supply

P592 units operate from a dc only auxiliary supply within the operative range of 19V to 300V.

Without energizing the P592 units measure the auxiliary supply to ensure it is within the operating range.

It should be noted that the P592 interface unit is designed to withstand an ac ripple component of up to 12% of the normal dc auxiliary supply. However, in all cases the peak value of the dc supply must not exceed the maximum specified operating limit.

Warning **Do not energize the P592 using the battery charger with the battery disconnected as this can irreparably damage the unit's power supply circuitry.**

6.2.5.5

P592 Light Emitting Diodes (LED's)

On power up the green '**SUPPLY HEALTHY**' LED should have illuminated and stayed on indicating that the P592 is healthy.

The four red LED's can be tested by appropriate setting of the DIL switches on the unit's front plate. Set the data rate switch according to the communication channel bandwidth available. Set all other switches to 0. To illuminate the '**DSR OFF**' and '**CTS OFF**' LED's, disconnect the V.35 connector from the rear of the P592 and set the '**DSR**' and '**CTS**' switches to '**0**'. The '**OPTO LOOPBACK**' and '**V.35 LOOPBACK**' LED's can be illuminated by setting their corresponding switches to '**1**'.

Once operation of the LED's has been established set all DIL switches, except for the '**OPTO LOOPBACK**' switch, to '**0**' and reconnect the V.35 connector.

6.2.5.6

P592 Optical Received Signal Level

With an optical cable connected to the MiCOM optical transmitter as instructed in section 6.2.2, disconnect the other end of the cable from the P592 Receiver (RX) and use an optical power meter to measure the received signal strength. The value should be in the range -16.8dBm to -25.4dBm. Record the measured value and replace the connector to the P592 receiver.

6.2.5.7

P592 Loopback

With the '**OPTO LOOPBACK**' switch in the '**1**' position the receive and transmit optical ports are electrically connected together. This allows the optical fiber communications between the P443/P446 relay and the P592 to be tested, but not the internal circuitry of the P592 itself.

6.2.5.8

P592 Optical Transmitter Signal Level

Using an appropriate fiber optic cable, connect the optical transmitter (TX) to an optical power meter. Check that the average power transmitted is within the range -16.8dBm to -22.8dBm.

Record the transmit power level.

Connect the appropriate optical fiber to connect the P592 transmitter to the MiCOM optical receiver and return to the MiCOM relay.

6.2.5.9 MiCOM Optical Received Signal Level from P592

Return to the MiCOM relay. Disconnect the fiber from the MiCOM optical receiver that connects to the optical transmitter of the P592 and measure the received signal level. The value should be in the range -16.8dBm to -25.4dBm. Record the measurement and then reconnect the fiber to the optical receiver.

6.2.6 Communications using P593 Interface Units (X.21)

Before loopback testing can begin, some other checks must be completed.

6.2.6.1 P593 Visual Inspection

Warning **ElectroStatic Discharge (ESD) precautions must be applied while the secondary cover is removed from the unit.**

If applicable replace the secondary front cover from the unit. Carefully examine the unit to see that no physical damage has occurred since installation.

The rating information given under the top access cover on the front of the unit should be checked to ensure it is correct for the particular installation.

Ensure that the case earthing connection, top left-hand corner at the rear of the case, is used to connect the unit to a local earth bar using an adequate conductor.

6.2.6.2 P593 Insulation

Insulation resistance tests are only necessary during commissioning if it is required for them to be done and they have not been performed during installation.

Isolate all wiring from the earth and test the insulation with an electronic or brushless insulation tester at a dc voltage not exceeding 500V. The auxiliary dc supply terminals should be temporarily connected together.

Warning **The X.21 circuits of the P593 are isolated from all other circuits but are electrically connected to the outer case. The circuits must not therefore be insulation or impulse tested to the case.**

The insulation resistance should be greater than 100MΩ at 500V.

On completion of the insulation resistance tests, ensure all external wiring is correctly reconnected to the P593.

6.2.6.3 P593 External Wiring

Check that the external wiring is correct to the relevant connection diagram or scheme diagram. The connection diagram number appears on the rating label under the top access cover on the front of the P593. The corresponding connection diagram will have been supplied with the Schneider Electric order acknowledgement for the P593.

Warning **It is especially important that the dc supplies are wired with the correct polarity.**

6.2.6.4 P593 Auxiliary Supply

P593 units operate from a dc only auxiliary supply within the operative range of 19.5V to 300V.

Without energizing the P593 units measure the auxiliary supply to ensure it is within the operating range.

It should be noted that the P593 interface unit is designed to withstand an ac ripple component of up to 12% of the normal dc auxiliary supply. However, in all cases the peak value of the dc supply must not exceed the maximum specified operating limit.

Warning **Do not energize the P593 using the battery charger with the battery disconnected as this can irreparably damage the unit's power supply circuitry.**

6.2.6.5 P593 Light Emitting Diodes (LED's)

On power up the green '**SUPPLY**' LED should have illuminated and stayed on indicating that the P593 is healthy.

Set the '**X.21 LOOPBACK**' switch to '**ON**'. The green '**CLOCK**' and red '**X.21 LOOPBACK**' LED's should illuminate. Reset the '**X.21 LOOPBACK**' switch to the '**OFF**' position.

Set the '**OPTO LOOPBACK**' switch to '**ON**'. The red '**OPTO LOOPBACK**' LED should illuminate. Do not reset the "**OPTO LOOPBACK**' switch as it is required in this position for the next test.

6.2.6.6 P593 Optical Received Signal Level

With an optical cable connected to the MiCOM optical transmitter as instructed in section 6.2.2, disconnect the other end of the cable from the P593 receiver (RX) and use an optical power meter to measure the received signal strength. The value should be in the range -16.8dBm to -25.4dBm. Record the measured value and replace the connector to the P593 receiver.

6.2.6.7 P593 Loopback Test

With the '**OPTO LOOPBACK**' switch in the '**ON**' position the receive and transmit optical ports are electrically connected together. This allows the optical fiber communications between the P443/P446 relay and the P593 to be tested, but not the internal circuitry of the P593 itself.

Set the '**OPTO LOOPBACK**' switch to '**OFF**' and '**X.21 LOOPBACK**' switch to '**ON**' respectively. With the '**X.21 LOOPBACK**' switch in this position the '**Receive Data**' and '**Transmit Data**' lines of the X.21 communication interface are connected together. This allows the optical fiber communications between the P443/P446 relay and the P593, and the internal circuitry of the P593 itself to be tested.

6.2.6.8 P593 Optical Transmitter Signal Level

Using an appropriate fiber optic cable, connect the P593 optical transmitter (TX) to an optical power meter. Check that the average power transmitted is within the range -16.8dBm to -22.8dBm.

Record the transmit power level.

Connect the appropriate optical fiber to connect the P592 transmitter to the MiCOM optical receiver and return to the MiCOM relay.

6.2.6.9 MiCOM Optical Received Signal Level from P593

Return to the MiCOM relay. Disconnect the fiber from the MiCOM optical receiver that connects to the optical transmitter of the P593 and measure the received signal level. The value should be in the range -16.8dBm to -25.4dBm. Record the measurement and then reconnect the fiber to the optical receiver.

6.2.7 Loopback Test

Set cell [0F14 IM64 Test Mode] to ‘**Enabled**’, and use cell [0F15 IM64 Test Pattern] to set a bit pattern to be sent via the InterMiCOM^{64} loopback. To verify the correct operation of loopback test, check in the [MEASUREMENTS 4] column that the contents of cell ‘**IM64 Rx Status**’ matches with the test pattern set. The communication statistics will indicate the number of valid and any errored messages received.

Note *The propagation delay measurement will not be valid in this mode of operation. The relay will now respond as if it is connected to a remote relay. The relay will indicate a loopback alarm which can only be cleared by setting the ‘**Test Loopback**’ to disabled.*

Note *In loopback mode the signals sent and received via the InterMiCOM^{64} interface continue to be routed to and from the signals defined in the programmable logic.*

Note *A test pattern can be also sent to the remote end in order to test the whole InterMiCOM communication path by enabling (OF14 IM64 Test Mode) and connecting two ends. If such a test is performed, special care has to be taken as the test pattern will be executed via PSL at the remote end.*

7 SETTING CHECKS

The setting checks ensure that all of the application-specific relay settings (i.e. both the relay's function and Programmable Scheme Logic (PSL) settings), for the particular installation, have been correctly applied to the relay.

If the application-specific settings are not available, ignore sections 7.1 and 7.2.

Note *The trip circuit should remain isolated during these checks to prevent accidental operation of the associated circuit breaker.*

7.1 Apply Application-Specific Settings

There are two methods of applying the settings to the relay:

- Transferring them from a pre-prepared setting file to the relay using a portable PC running the appropriate software via the relay's front EIA(RS)232 port, located under the bottom access cover, or rear communications port (with a KITZ protocol converter connected). This method is preferred for transferring function settings as it is much faster and there is less margin for error. If PSL other than the default settings with which the relay is supplied are to be used then this is the only way of changing the settings.
- If a setting file has been created for the particular application and provided on a diskette, this will further reduce the commissioning time and should always be the case where application-specific PSL is to be applied to the relay.
- Enter them manually via the PSL.

Warning **It is essential that where the installation needs application-specific PSL, that the appropriate .psl file, is downloaded (sent) to the relay, for each and every setting group that will be used. If the user fails to download the required .psl file to any setting group that may be brought into service, then factory default PSL will still be resident. This may have severe operational and safety consequences.**

Note *If (fiber) InterMiCOM^{64} command signaling is being used, it may be necessary to remove the power and re-energize the relay after the settings have been changed : If the communication mode [2010 Comms Mode] has been changed, then a '**comms changed**' alarm will be raised that can only be cleared by power cycling the relay.*

7.1.1 InterMiCOM Loopback

If either MODEM InterMiCOM, or Fiber InterMiCOM^{64} is being used for the signaling channel, the communication loopbacks that were tested earlier need to be maintained whilst scheme testing is being performed.

For InterMiCOM^{64} cell [0F13 Test Loopback] should be set to '**External**', the contents of cell [0F15 IM64 TestPattern] should have all bits set to '**0**' initially, and cell [0F15 IM64 Test Mode] should be set to '**Enabled**'.

For MODEM InterMiCOM, cell [1550 Loopback Mode] should be set to '**External**' and the test pattern should have all bits set to '**0**' initially.

7.1.2 Reset Statistics

The InterMiCOM communications statistics should be reset at this point. For MODEM InterMiCOM the [1531 Reset Statistics] in the InterMiCOM COMMS column of the menu is used. For InterMiCOM^{64} the [0530 Clear Statistics] cell in the MEASUREMENTS 4 column should be used.

7.2 Demonstrate Correct Relay Operation

Tests 5.2.10 and 5.2.11 have already demonstrated that the relay is within calibration, thus the purpose of these tests is as follows:

- To determine that the primary protection function of the relay, distance (or delta directional comparison) can trip according to the correct application settings.
- To verify correct setting of any aided scheme DEF (ground overcurrent) protection.

7.2.1 Distance Protection Single-End Testing

If the distance protection function is being used, the reaches and time delays should be tested. If not, skip to section 0

To avoid spurious operation of any delta directional, overcurrent, DEF/earth fault or breaker fail elements, these should be disabled for the duration of the distance element tests. This is done in the relay's CONFIGURATION column. Ensure that cells [090C: Directional E/F DEF], [0910: Overcurrent], [0913: Earth Fault] and [0920: CB Fail] are all set to "**Disabled**". Make a note of which elements need to be re-enabled after testing.

7.2.1.1 Connection and Preliminaries

The relay should now be connected to equipment able to supply phase-phase and phase-neutral volts with current in the correct phase relation for a particular type of fault on the selected relay characteristic angle. The facility for altering the loop impedance (phase-to-ground fault or phase-phase) presented to the relay is essential.

It is recommended that a three phase digital/electronic injection test set is used for ease of commissioning. If this is not available, two setting changes may need to be made on the relay, for the duration of testing:

1. In order to facilitate testing of the Distance elements using test sets which do not provide a dynamic model to generate true fault delta conditions, a Static Test Mode setting is provided. This setting is found in the COMMISSIONING TESTS menu column. When set, this disables phase selector control and forces the relay to use a conventional (non-delta) directional line.

2. For lower specification test equipment that cannot apply a full three phase set of healthy simulated pre-fault voltages, the VT supervision may need to be disabled to avoid spurious pickup. This is achieved in the CONFIGURATION column, by setting cell [0921: Supervision] to "**Disabled**").

Connect the test equipment to the relay via the test block(s) taking care not to open-circuit any CT secondary. If MMLG type test blocks are used, the live side of the test plug **must** be provided with shorting links before it is inserted into the test block.

7.2.1.2 Zone 1 Reach Check

The zone 1 element is set to be directional forward.

Apply a dynamic A phase to neutral fault, slightly in excess of the expected reach. The duration of the injection should be in excess of the tZ1 timer setting, but less than tZ2 (settings found in the DISTANCE menu column). Observe that no trip should occur, and the red Trip LED remains extinguished.

Reduce the impedance and reapply this to the relay. This procedure should be repeated until a trip occurs. The display will show Alarms/Faults present and the Alarm and Trip LEDs will illuminate. To view the alarm message press the read key 📖, repeat presses of this key should be used to verify that phase A was the "**Start Element**". Keep pressing the 📖 key until the yellow alarm LED changes from flashing to being steadily on. At the prompt '**Press clear to reset alarms**', press the '**C**' key. This will clear the fault record from the display

Record the impedance at which the relay tripped. The measured impedance should be within +/- 10% of the expected reach.

Modern injection test sets usually calculate the expected fault loop impedance from the relay settings, for those that do not:

- Connections for an A-N fault. The appropriate loop impedance is given by the vector sum:
- Z1 + Z1 residual = Z1 + (Z1 x kZN Res Comp∠kZN Angle) Ω.

7.2.1.3 Zone 2 Reach Check

The zone 2 element is set to be directional forward.

Apply a dynamic B-C fault, slightly in excess of the expected reach. The duration of the injection should be in excess of the tZ2 timer setting, but less than tZ3. Repeat as in 7.2.1.2 to find the zone reach.

Record the impedance at which the relay tripped. The measured impedance should be within +/- 10% of the expected reach. Read and reset the alarms.

Modern injection test sets usually calculate the expected fault loop impedance from the relay settings, for those that do not:

Connections for a B-C fault. The reach for phase-phase should be checked and the operation of the appropriate contacts confirmed. The appropriate loop impedance is now given by:

2 x Z2 Ω

7.2.1.4 Zone 3 Reach Check

The zone 3 element is set to be directional forward.

Apply a dynamic C-A fault, slightly in excess of the expected reach. The duration of the injection should be in excess of the tZ3 timer setting (typically tZ3 + 100ms). Repeat as in 7.2.1.2 to find the zone reach.

Record the impedance at which the relay tripped. The measured impedance should be within +/- 10% of the expected reach. Read and reset the alarms.

Only a visual check that the correct reverse offset (Z3') has been applied is needed. The setting is found in cell [3143: Z3' Ph Rev Reach] and [31A3: Z3' Gnd Rev Reach].

7.2.1.5 Zone 4 Reach Check (if Enabled)

The zone 4 element is set to be directional reverse.

Apply a dynamic B-N fault, slightly in excess of the expected reach. The duration of the injection should be in excess of the tZ4 timer setting (typically tZ4 + 100ms). Repeat as in 7.2.1.2 to find the zone reach.

Record the impedance at which the relay tripped. The measured impedance should be within +/- 10% of the expected reach. Read and reset the alarms.

7.2.1.6 Zone P Reach Check (if Enabled)

The zone P element can be set to be forward or reverse directional. The current injected must be in the appropriate direction to match the setting in the “**DISTANCE SETUP**” menu column (cells [3151] and [31B1]).

Apply a dynamic C-N fault, slightly in excess of the expected reach. The duration of the injection should be in excess of the tZP timer setting (typically tZP + 100ms). Repeat as in 7.2.1.2 to find the zone reach.

Record the impedance at which the relay tripped. The measured impedance should be within +/- 10% of the expected reach. Read and reset the alarms.

7.2.1.7 Resistive Reach (Quadrilateral Characteristics only)

Only a visual check that the correct settings for phase and ground element resistive reaches have been applied is needed. The relevant settings are R1Ph, R2Ph, R3Ph, R3Ph reverse, R4Ph and RP Ph for phase fault zones. The settings are R1Gnd, R2Gnd, R3Gnd, R3Gnd reverse, R4Gnd and RP Gnd for ground fault zones.

Note *Zone 3 has an independent setting for the forward resistance reach (right-hand resistive reach line), and the reverse resistance reach (left-hand resistive reach line).*

7.2.1.8 Load Blinder

Only a visual check that the correct settings for the load blinder have been applied is needed. The settings are found at the end of the DISTANCE SETUP menu column, cells [31D4] to [31D6]. It must be verified that [31D5: Load B/Angle] is set at least 10 degrees less than the [3004: Line Angle] setting in the LINE PARAMETERS menu column.

7.2.2 Distance Protection Operation and Contact Assignment

7.2.2.1 Phase A

Prepare a dynamic A phase to neutral fault, at half the Zone 1 reach. Connect a timer to start when the fault injection is applied, and to stop when the trip occurs. To verify correct output contact mapping use the trip contacts that would be expected to trip the circuit breaker(s), as shown in the table. For two breaker applications, stop the timer once CB1 and CB2 trip contacts have both closed, monitored by connecting the contacts in series to stop the timer if necessary.

	Single Breaker	Two Circuit Breakers
Three Pole Tripping	Any Trip	Any Trip (CB1) and Any Trip (CB2)
Single Pole Tripping	Trip A	Trip A (CB1) and Trip A (CB2)

Apply the fault and record the phase A trip time. Switch OFF the ac supply and reset the alarms.

7.2.2.2 Phase B

Reconfigure to test a B phase fault. Repeat the test in 7.2.2.1, this time ensuring that the breaker trip contacts relative to B phase operation close correctly. Record the phase B trip time. Switch OFF the ac supply and reset the alarms.

7.2.2.3 Phase C

Repeat 7.2.2.2 for the C phase.

The average of the recorded operating times for the three phases should typically be less than 20ms for 50Hz, and less than 16.7ms for 60Hz when set for instantaneous operation. Switch OFF the ac supply and reset the alarms.

- Where a non-zero tZ1 Gnd time delay is set in the DISTANCE menu column, the expected operating time is typically within +/- 5% of the tZ1 setting plus the "**instantaneous**" delay quoted above.

7.2.2.4 Time Delay Settings tZ1 Ph, and tZ2 - tZ4

Only a visual check that the correct time delay settings have been applied is needed. The relevant settings in the SCHEME LOGIC column are:

[3409: tZ1 Ph Time Delay]

[3411: tZ2 Ph Time Delay] and [3412: tZ2 Gnd Time Delay]

[3419: tZ3 Ph Time Delay] and [341A: tZ3 Gnd Time Delay]

[3421: tZP Ph Time Delay] and [3422: tZP Gnd Time Delay]

[3429: tZ4 Ph Time Delay] and [342A: tZ4 Gnd Time Delay]

Note	*The P443/P446 allows separate time delay settings for phase ("**Ph**") and ground ("**Gnd**") fault elements. BOTH must be checked to ensure that they have been set correctly.*

7.2.3 Distance Protection Scheme Testing

The relay will be tested for it's response to internal and external fault simulations, but the engineer must note that the response will depend upon the aided channel (pilot) scheme that is selected. For a conventional signaling scheme, the table overleaf indicates the expected response for various test scenarios, according to the scheme selection, and status of the opto-input that is assigned to the "**Aided Receive Ext**" channel receive for the distance scheme. The response to the "**Reset Z1 Extension**" opto is shown in the case of a Zone 1 Extension scheme.

Scheme testing of the MiCOM relay is detailed in the case of conventional scheme implementation. In the case where an InterMiCOM scheme is being employed to provide the signalling, it may be that the scheme logic does not use opto-inputs for the aided scheme implementation and that internal logic signals (DDBs) will need to be set/reset in order to test the operation of the protection scheme. With InterMiCOM^{64}, it should be possible to use the IM64 Test Mode in conjunction with the IM64 Test Pattern to assert/monitor the relevant signal. With MODEM InterMiCOM, it may be more difficult due to the different way that the Test Pattern is implemented such that, in MODEM InterMiCOM applications, it may be that the scheme testing has to be delayed until the end-to-end tests can be performed.

Ensure that the injection test set timer is still connected to measure the time taken for the relay to trip. A series of fault injections will be applied, with a Zone 1, end-of-line, or Zone 4 fault simulated. At this stage, merely note the method in which each fault will be applied, but do not inject yet:

Zone 1 fault	A dynamic forward A-B fault at half the Zone 1 reach will be simulated.
End of line fault	A dynamic forward A-B fault at the remote end of the line will be simulated. The fault impedance simulated should match the [3003: Line Impedance] setting in the LINE PARAMETERS menu column.

- Zone 4 fault — A dynamic reverse A-B fault at half the Zone 4 reach will be simulated.

Fault Type Simulated	**RELAY RESPONSE**					
	Forward Fault in Zone 1		**Forward Fault at End of Line (Within Z1X/Z2)**		**Reverse Fault in Zone 4**	
Signal Receive Opto	ON	OFF	ON	OFF	ON	OFF
Zone 1 Extension	Trip	Trip	No trip	Trip	No trip	No trip
Blocking Scheme	Trip, No signal send	Trip, No signal send	No trip, No signal send	Trip, No signal send	No trip, Signal send	No trip, Signal send
Permissive Scheme (PUR/PUTT)	Trip, Signal send	Trip, Signal send	Trip, No signal send	Trip, No signal send	No trip, No signal send	No trip, No signal send
Permissive Scheme (POR/POTT)	Trip, Signal send	Trip, Signal send	Trip, Signal send	No trip, Signal send	No trip, No signal send	No trip, No signal send

7.2.3.1 Scheme Trip Test for Zone 1 Extension only

The Reset Zone 1 Extension opto input should first be ON (energized). This should be performed by applying a continuous DC voltage onto the required opto input, either from the test set, station battery, or relay field voltage (commissioning engineer to ascertain the best method).

With the opto energized, inject an end of line fault. The duration of injection should be set to 100ms. No trip should occur.

De-energize the Reset Z1X opto (remove the temporary energization link, to turn it OFF).

Repeat the test injection, and record the operating time. This should typically be less than 20ms for 50Hz, and less than 16.7ms for 60Hz when set for instantaneous operation. Switch OFF the ac supply and reset the alarms.

- Where a non-zero tZ1 Ph time delay is set in the DISTANCE menu column, the expected operating time is typically within +/- 5% of the tZ1 setting plus the "**instantaneous**" delay quoted above.

7.2.3.2 Scheme Trip Tests for Permissive Schemes (PUR/POR only)

This test applies to both Permissive Underreach, and Permissive Overreach aided scheme applications.

As in the table, for a Permissive scheme the Signal Receive opto input will need to be ON (energized). This should be performed by applying a continuous DC voltage onto the required opto input, either from the test set, station battery, or relay field voltage (commissioning engineer to ascertain the best method).

With the opto energized, inject an end of line fault, and record the operating time. The measured operating time should typically be less than 20ms for 50Hz, and less than 16.7ms for 60Hz when set for instantaneous operation. Switch OFF the ac supply and reset the alarms.

- Where a non-zero Distance Dly time delay is set in the DISTANCE menu column, the expected operating time is typically within +/- 5% of the tZ1 setting plus the "**instantaneous**" delay quoted above.

De-energize the channel received opto (remove the temporary energization link, to turn it OFF).

7.2.3.3 Scheme Trip Tests for Blocking Scheme only

The Signal Receive opto input should first be ON (energized). This should be performed by applying a continuous DC voltage onto the required opto input, either from the test set, station battery, or relay field voltage (commissioning engineer to ascertain the best method).

With the opto energized, inject an end of line fault. The duration of injection should be set to 100ms. No trip should occur.

De-energize the channel received opto (remove the temporary energization link, to turn it OFF).

Repeat the test injection, and record the operating time. Switch OFF the ac supply and reset the alarms.

- For blocking schemes, a non-zero Distance Dly time delay is set, so the expected operating time is typically within +/- 5% of the delay setting plus the P443/P446 “**instantaneous**” operating delay. The trip time should thus be less than 20ms for 50Hz, and less than 16.7ms for 60Hz, plus 1.05 x Delay setting.

7.2.3.4 Signal Send Test for Permissive Schemes (PUR/POR only)

This test applies to both Permissive Underreach, and Permissive Overreach scheme applications.

Firstly, reconnect the test set so that the timer is no longer stopped by the Trip contact, but is now stopped by the **Signal Send contact** (the contact that would normally be connected to the pilot/signaling channel).

Inject a Zone 1 fault, and record the signal send contact operating time. The measured operating time should typically be less than 20ms for 50Hz, and less than 16.7ms for 60Hz applications. Switch OFF the ac supply and reset the alarms.

7.2.3.5 Signal Send Test for Blocking Scheme only

Firstly, reconnect the test set so that the timer is no longer stopped by the Trip contact, but is now stopped by the **Signal Send contact** (the contact that would normally be connected to the pilot/signaling channel).

Inject a Zone 4 fault, and record the signal send contact operating time. The measured operating time should typically be less than 20ms for 50Hz, and less than 16.7ms for 60Hz applications. Switch OFF the ac supply and reset the alarms.

7.2.4 Scheme Timer Settings

Only a visual check that the correct time delay settings have been applied is needed. The relevant settings in the AIDED SCHEMES column are:

• [344A: tRev. Guard]	if applicable/visible
• [344B: Unblocking Delay]	if applicable/visible
• [3453: WI Trip Delay]	if applicable/visible

Warning **Upon completion of the tests any delta directional, DEF, overcurrent, earth fault, breaker fail or supervision elements which were disabled for testing purposes must have their original settings restored in the CONFIGURATION column. Ensure that the Static Test Mode has been left *Disabled*. Ensure that any wires/leads temporarily fitted to energize the channel receive opto input have been removed.**

7.2.5 Delta Directional Comparison

If the delta directional comparison aided scheme is being used, the operation should be tested. If not, skip to section 0.

To avoid spurious operation of any distance, overcurrent, DEF/earth fault or breaker fail elements, these should be disabled for the duration of the delta element tests. This is done in the relay's CONFIGURATION column. Ensure that cells [090B: Distance], [090C: DEF], [0910: Overcurrent], [0913: Earth Fault] and [0920: CB Fail] are all set to "**Disabled**". Make a note of which elements need to be re-enabled after testing.

7.2.5.1 Connection and Preliminaries

It is recommended that a 3-phase digital/electronic injection test set is used for ease of commissioning.

Connect the test equipment to the relay via the test block(s) taking care not to open-circuit any CT secondary. If MMLG type test blocks are used, the live side of the test plug must be provided with shorting links before it is inserted into the test block.

7.2.5.2 Single-Ended Injection Test

This set of injection tests aims to determine that a single MiCOM P443/P446 relay, at one end of the scheme is performing correctly. The relay is tested in isolation, with the communications channel to the remote line terminal disconnected. Verify that the P443/P446 relay cannot send or receive channel scheme signals to/from the remote line end.

The relay will be tested for it's response to forward and reverse fault injections, but the engineer must note that the response will depend upon the aided channel (pilot) scheme that is selected. For a conventional signaling scheme, the following table indicates the expected response for various test scenarios, according to the scheme selection, and status of the opto-input that is assigned to the "**Aided Receive Ext**" channel receive for the delta scheme.

Scheme testing of the MiCOM relay is detailed in the case of conventional scheme implementation. In the case where an InterMiCOM scheme is being employed to provide the signalling, it may be that the scheme logic does not use opto-inputs for the aided scheme implementation and that internal logic signals (DDBs) will need to be set/reset in order to test the operation of the protection scheme. With InterMiCOM^{64}, it should be possible to use the IM64 Test Mode in conjunction with the IM64 Test Pattern to assert/monitor the relevant signal or check for signal operation. With MODEM InterMiCOM, it may be more difficult due to the different way that the Test Pattern is implemented such that, in MODEM InterMiCOM applications, it may be that the scheme testing has to be delayed until the end-to-end tests can be performed.

Direction of Fault Test Injection	RELAY RESPONSE			
	Forward Fault		Reverse Fault	
Signal Receive Opto	ON	OFF	ON	OFF
Blocking Scheme	No trip, No signal send	Trip, No signal send	No trip, Signal send	No trip, Signal send
Permissive Scheme (POR/POTT)	Trip, Signal send	No trip, Signal send	No trip, No signal send	No trip, No signal send

7.2.5.3 Forward Fault Preparation

Configure the test set to inject a dynamic sequence of injection, as follows:

- Step 1 Simulate a healthy three-phase set of balanced voltages, each of magnitude Vn. No load current should be simulated. The duration of injection should be set to 1 second. Step 1 thus mimics a healthy unloaded line, prior to the application of a fault
- Step 2 Simulate a forward fault on the A-phase. The A-phase voltage must be simulated to drop by 3 times the [3313: ΔV Fwd] setting, i.e:

$$Va = Vn - 3 \times \Delta V\ Fwd$$

The fault current on the A-phase should be set to 3 times the [3315: ΔI Fwd] setting, lagging Va by a phase angle equal to the line angle, i.e:

$$Ia = 3 \times \Delta I\ Fwd\ \angle{-\theta}\ Line$$

Phases B and C should retain their healthy prefault voltage, and no current. The duration of injection should be set to 100ms longer than the *Delta Dly* time setting.

7.2.6 Delta Directional Comparison Operation and Contact Assignment

A forward fault will be injected as described above, with the intention to cause a scheme trip. As in the table, for a Permissive scheme the Signal Receive opto input will need to be ON (energized). This should be performed by applying a continuous DC voltage onto the required opto input, either from the test set, station battery, or relay field voltage (commissioning engineer to ascertain the best method).

For a Blocking scheme, the opto should remain de-energized ("**OFF**").

7.2.6.1 Phase A

Prepare a dynamic A phase to neutral fault, as detailed above. Ensure that the test set is simulating Steps 1 and 2 as one continuous transition. Connect a timer to start when the **fault** injection (Step 2) is applied, and to stop when the trip occurs. To verify correct output contact mapping use the trip contacts that would be expected to trip the circuit breaker(s), as shown in the table. For two breaker applications, stop the timer once CB1 and CB2 trip contacts have both closed, monitored by connecting the contacts in series to stop the timer if necessary.

	Single Breaker	Two Circuit Breakers
Three Pole Tripping	Any Trip	Any Trip (CB1) and Any Trip (CB2)
Single Pole Tripping	Trip A	Trip A (CB1) and Trip A (CB2)

Apply the fault and record the phase A trip time. Switch OFF the ac supply and reset the alarms.

7.2.6.2 Phase B

Reconfigure to test a B phase fault. Repeat the test in 7.2.6.1, this time ensuring that the breaker trip contacts relative to B phase operation close correctly. Record the phase B trip time. Switch OFF the ac supply and reset the alarms.

7.2.6.3 Phase C

Repeat 7.2.6.2 for the C phase.

The average of the recorded operating times for the three phases should typically be less than 20ms for 50Hz, and less than 16.7ms for 60Hz when set for instantaneous operation, as in Permissive schemes. Switch OFF the ac supply and reset the alarms.

- For Blocking schemes, where a non-zero Delta Dly time delay is set, the expected operating time is typically within +/- 5% of the delay setting plus the "**instantaneous**" delay quoted above.

7.2.7 Delta Directional Comparison Scheme Testing

7.2.7.1 Signal Send Test for Permissive Schemes (POR/POTT only)

Firstly, reconnect the test set so that the timer is no longer stopped by the Trip contact, but is now stopped by the **Signal Send Contact** (the contact that would normally be connected to the pilot/signaling channel).

Repeat the forward fault injection, and record the signal send contact operating time. The measured operating time should typically be less than 20ms for 50Hz, and less than 16.7ms for 60Hz applications. Switch OFF the ac supply and reset the alarms.

7.2.7.2 Signal Send Test for Blocking Schemes Only

Configure the test set to inject a dynamic sequence of injection, as follows:

- Step 1 Simulate a healthy three-phase set of balanced voltages, each of magnitude Vn. No load current should be simulated. The duration of injection should be set to 1 second. Step 1 thus mimics a healthy unloaded line, prior to the application of a fault
- Step 2 Simulate a reverse fault on the A-phase. The A-phase voltage must be simulated to drop by 3 times the [3314: ΔV Rev] setting, i.e.:

$$V_a = V_n - 3 \times \Delta V \text{ Rev}$$

The fault current on the A-phase should be set to 3 times the [3316: ΔI Rev] setting, and in antiphase to the forward injections, i.e:

$$I_a = 3 \times \Delta I \text{ Rev} \angle 180^\circ - \theta \text{ Line}$$

Phases B and C should retain their healthy prefault voltage, and no current. The duration of injection should be set to 100ms.

Prepare the dynamic A phase reverse fault, as detailed above. Ensure that the test set is simulating Steps 1 and 2 as one continuous transition. Connect a timer to start when the **fault** injection (Step 2) is applied, and to stop when the Delta scheme "**Signal Send**" contact closes. Apply the test, and record the signal send contact response time. Switch OFF the ac supply and reset the alarms.

The recorded operating time should typically be less than 20ms for 50Hz, and less than 16.7ms for 60Hz applications.

Warning **Upon completion of the tests any distance, DEF, overcurrent, earth fault, breaker fail or supervision elements which were disabled for testing purposes must have their original settings restored in the CONFIGURATION column. Ensure that any wires/leads temporarily fitted to energize the channel receive opto input have been removed.**

7.2.8 Directional Earth Fault Aided Scheme (Ground Current Pilot Scheme)

If the Aided DEF protection function is being used, it should be tested. If not, skip to section 0.

To avoid spurious operation of any distance, overcurrent, earth fault or breaker fail elements, these should be disabled for the duration of the DEF tests. This is done in the relay's CONFIGURATION column. Make a note of which elements need to be re-enabled after testing.

DEF testing of the MiCOM relay is detailed in the case of conventional scheme implementation. In the case where an InterMiCOM scheme is being employed to provide the signalling, it may be that the scheme logic does not use opto-inputs for the aided scheme implementation and that internal logic signals (DDBs) will need to be set/reset in order to test the operation of the protection scheme. With InterMiCOM^{64}, it should be possible to use the IM64 Test Mode in conjunction with the IM64 Test Pattern to assert/monitor the relevant signal. With MODEM InterMiCOM, it may be more difficult due to the different way that the Test Pattern is implemented such that, in MODEM InterMiCOM applications, it may be that the scheme testing has to be delayed until the end-to-end tests can be performed.

This set of injection tests aims to determine that a single P443/P446 relay, at one end of the scheme is performing correctly. The relay is tested in isolation, with the communications channel to the remote line terminal disconnected. Verify that the P443/P446 relay cannot send or receive channel scheme signals to/from the remote line end.

7.2.8.1 Connect the Test Circuit

Determine which output relay(s) has/have been selected to operate when a DEF trip occurs by viewing the relay's programmable scheme logic.

If the trip outputs are phase-segregated (i.e. a different output relay allocated for each phase), the relay assigned for tripping on '**A**' phase faults should be used.

Connect the output relay so that its operation will trip the test set and stop the timer.

Connect the current output of the test set to the '**A**' phase current transformer input of the relay. Connect, all three phase voltages to the relay Va, Vb, and Vc. Ensure that the timer will start when the current is applied to the relay.

Ensure that the timer is reset, and prepare the test shot below:

- Simulate a forward fault on the A-phase. The A-phase voltage must be simulated to drop by 4 times the [3905] or [3906] : "**DEF Vpol**" setting, i.e.:

  Va = Vn - (4 x DEF Vpol)

The fault current on the A-phase should be set to 2 times the [3907: DEF Threshold] setting, and in the forward direction. For a forward fault, the current Ia should lag the voltage Va by the "**DEF Char Angle**" setting, i.e.:

$$Ia = 2 \times IN_{\text{DEF Threshold}} \angle \theta_{\text{DEF}}$$

Phases B and C should retain their healthy prefault voltage, and no current. The duration of the injection should be in excess of the **DEF Delay** setting (typically tDEF Delay + 100ms).

Direction of Fault Test Injection	**RELAY RESPONSE**			
	Forward Fault		**Reverse Fault**	
Signal Receive Opto	ON	OFF	ON	OFF
Blocking Scheme	No trip, No signal send	Trip, No signal send	No trip, Signal send	No trip, Signal send
Permissive Scheme (POR/POTT)	Trip, Signal send	No trip, Signal send	No trip, No signal send	No trip, No signal send

A forward fault will be injected as described, with the intention to cause a scheme trip. As in the table, for a Permissive scheme the Signal Receive opto input will need to be ON (energized). This should be performed by applying a continuous DC voltage onto the required opto input, either from the test set, station battery, or relay field voltage (commissioning engineer to ascertain the best method).

For a blocking scheme, the opto should remain de-energized (“**OFF**”).

7.2.8.2 DEF Aided Scheme - Forward Fault Trip Test

Apply the fault and record the (phase A) trip time. Switch OFF the ac supply and reset the alarms.

- The aided ground fault (DEF) scheme trip time for POR schemes should be less than 40ms.
- For blocking schemes, where a non-zero DEF Dly time delay is set, the expected operating time is typically within +/- 5% of the delay setting plus the “**instantaneous**” (40ms) delay quoted above.
- There is no need to repeat the test for phases B and C, as these trip assignments have already been proven by the distance/delta trip tests.

7.2.9 DEF Aided Scheme - Scheme Testing

7.2.9.1 Signal Send Test for Permissive Schemes (POR/POTT only)

Firstly, reconnect the test set so that the timer is no longer stopped by the Trip contact, but is now stopped by the **Signal Send Contact** (the contact that would normally be connected to the pilot/signaling channel).

Repeat the forward fault injection, and record the signal send contact operating time. The measured operating time should typically be less than 40ms. Switch OFF the ac supply and reset the alarms.

7.2.9.2 Signal Send Test for Blocking Schemes only

Firstly, reconnect the test set so that the timer is no longer stopped by the Trip contact, but is now stopped by the **Signal Send contact** (the contact that would normally be connected to the pilot/signaling channel).

Secondly, reverse the current flow direction on the “**A**” phase, to simulate a reverse fault.

Perform the reverse fault injection, and record the signal send contact operating time. The measured operating time should typically be less than 40ms. Switch OFF the ac supply and reset the alarms.

Warning **Upon completion of the tests any delta directional, distance, overcurrent, earth fault, breaker fail or supervision elements which were disabled for testing purposes must have their original settings restored in the CONFIGURATION column. Ensure that any wires/leads temporarily fitted to energize the channel receive opto input have been removed.**

7.2.10 Out of Step Tripping (OST) Protection

If the Out of Step Tripping (OST) protection function is being used, it should be tested. If not, skip to section 9.

OST protection applies only to MiCOM relays with hardware version J or later, and with software version 33 or later.

This test is suitable for injection sets with a state sequencer function as dynamic impedance conditions are going to be tested. Up to four states impedances that will be applied during the Out of Step commissioning are presented in Figure 6.

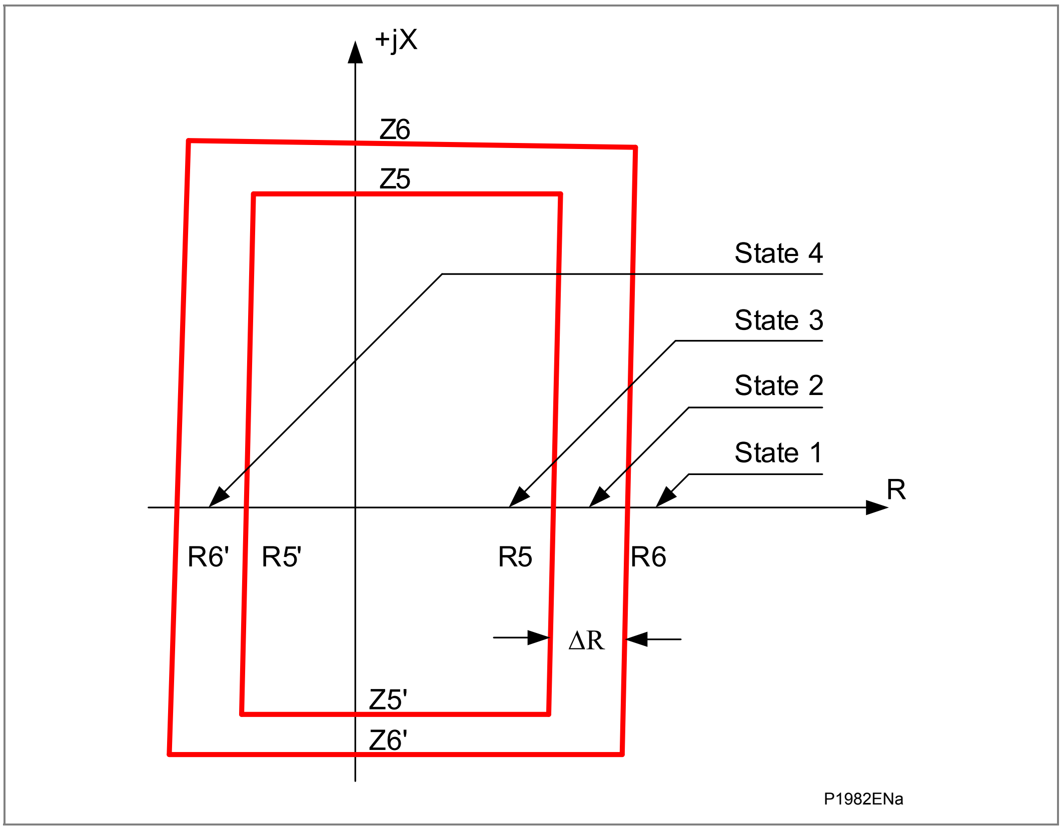

Figure 6 - Four state impedances

Depending on the Out of Step settings, follow one of the three options.

7.2.10.1 Predictive OST Setting

Clear all alarms. Set Tost to zero. Based on healthy voltages (VA = VB = VC = 57.8V) calculate the currents to generate the impedances as per Table 12.

	State 1	State 2	State 3
Apply IA = IB = IC =	$\frac{57.8}{1.1*R6}$	$\frac{57.8}{R5+\frac{1}{2}(R6-R5)}$	$\frac{57.8}{0.9*R5}$
Angle	0°	0°	0°
Duration	500ms	Longer than 25ms but shorter that Delta t' set time	500ms

Table 12 - Predictive OST state sequence

Note	*Angle in the table above is the angle between voltages and their respective currents.*

Now apply the 3 state sequence to the relay under test and observe that the relay has tripped 3 phase and that an associated '**Predictive OST**' alarm is displayed on the local LCD.

Clear all alarms.

7.2.10.2 OST Setting

Clear all alarms. Set Tost to zero. Based on healthy voltages (VA = VB = VC = 57.8V) calculate the currents to generate the impedances as per Table 13.

	State 1	State 2	State 3	State 4
Apply IA = IB = IC =	$\frac{57.8}{1.1*R6}$	$\frac{57.8}{R5+\frac{1}{2}(R6-R5)}$	$\frac{57.8}{0.9*R5}$	$\frac{57.8}{1.1*R5'}$
Angle	0°	0°	0°	180°
Duration	500ms	Longer than Delta t' set time	100ms	500ms

Table 13 - OST state sequence

Note	*Angle in the table above is the angle between voltages and their respective currents. Also note that in state 4 the currents are displaced 180° from their respective voltages.*

Now apply the 4 state sequence to the relay under test and observe that the relay has tripped 3-phase and that an associated '**OST**' alarm is displayed on the local LCD.

7.2.10.3 Predictive and OST Setting

As per '**Predictive OST**' above.

7.2.10.4 'Tost' Timer Test

Repeat the test as for '**Predictive OST**' and observe that the 3phase tripping will come up after '**Tost**' set time delay. Record the operating time in the commissioning record sheet.

7.2.11 Backup Phase Overcurrent Protection

If the overcurrent protection function is being used, the I>1 element should be tested. If not, skip to section 7.3 .

To avoid spurious operation of any delta directional, distance, DEF, earth fault or breaker fail elements, these should be disabled for the duration of the overcurrent tests. This is done in the relay’s CONFIGURATION column. Make a note of which elements need to be re-enabled after testing.

7.2.11.1 Connect the Test Circuit

Determine which output relay has been selected to operate when an I>1 trip occurs by viewing the relay’s programmable scheme logic.

The relay assigned for Trip Output A (DDB 523) faults should be used.

Stage 1 should be mapped directly to an output relay in the programmable scheme logic. If default PSL is used, Relay 3 can be used as I1> is mapped to Trip inputs 3 Ph (DDB 529) that in turn is internally mapped to Any Trip (DDB 522) mapped to relay 3 (see trip conversion logic on section P44y/EN OP) .

Connect the output relay so that its operation will trip the test set and stop the timer.

Connect the current output of the test set to the ‘**A**’ phase current transformer input of the relay (terminals C3 and C2 where 1A current transformers are being used and terminals C1 and C2 for 5A current transformers).

If [3503: GROUP 1 OVERCURRENT, I>1 Directional] is set to ‘**Directional Fwd**’, the current should flow out of terminal C2 but into C2 if set to ‘**Directional Rev**’.

If cell [3503: GROUP 1 OVERCURRENT, I>1 Directional] has been set to ‘**Directional Fwd**’ or ‘**Directional Rev**’ then rated voltage should be applied to terminals C20 and C21.

Ensure that the timer will start when the current is applied to the relay.

Note	*If the timer does not stop when the current is applied and stage 1 has been set for directional operation, the connections may be incorrect for the direction of operation set. Try again with the current connections reversed.*

7.2.11.2 Perform the Test

Ensure that the timer is reset.

Apply a current of twice the setting in cell [3504: GROUP 1 OVERCURRENT, I>1 Current Set] to the relay and note the time displayed when the timer stops.

Check that the red trip LED has illuminated.

7.2.11.3 Check the Operating Time

Check that the operating time recorded by the timer is within the range shown in Table 14.

Note	*Except for the definite time characteristic, the operating times given in Table 11 are for a time multiplier or time dial setting of 1. Therefore, to obtain the operating time at other time multiplier or time dial settings, the time given in Table 12 must be multiplied by the setting of cell [3506: GROUP 1 OVERCURRENT, I>1 TMS] for IEC and UK characteristics or cell [3507: GROUP 1 OVERCURRENT, Time Dial] for IEEE and US characteristics.*

In addition, for definite time and inverse characteristics there is an additional delay of up to 0.02 second and 0.08 second respectively that may need to be added to the relay’s acceptable range of operating times.

For all characteristics, allowance must be made for the accuracy of the test equipment being used.

Characteristic	Operating Time at Twice Current Setting and Time Multiplier/Time Dial Setting of 1.0	
	Nominal (seconds)	Range (seconds)
DT	[3505: I>1 Time Delay] setting	Setting ±2%
IEC S Inverse	10.03	9.53 - 10.53
IEC V Inverse	13.50	12.83 - 14.18
IEC E Inverse	26.67	24.67 - 28.67
UK LT Inverse	120.00	114.00 - 126.00
IEEE M Inverse	3.8	3.61 - 4.0
IEEE V Inverse	7.03	6.68 - 7.38
IEEE E Inverse	9.50	9.02 - 9.97
US Inverse	2.16	2.05 - 2.27
US ST Inverse	12.12	11.51 - 12.73

Table 14 - Characteristic operating times for I>1

Warning **Upon completion of the tests any delta directional, distance, overcurrent, earth fault, breaker fail or supervision elements which were disabled for testing purposes must have their original settings restored in the CONFIGURATION column.**

7.3 Check Trip and Auto-Reclose Cycle

If the auto-reclose function is being used, the circuit breaker trip and auto-reclose cycle can be tested automatically at the application-specific settings.

In order to test the trip and close operation without operating the breaker, the following criterion must be satisfied:

- The "**CB Healthy**" DDB should not be mapped, or if it is mapped, it must be asserted high
- The CB status inputs (52A, etc.) should not be mapped, or if they are mapped, they should be activated so as to mimic the circuit breaker operation
- If configured for single pole tripping, appropriate voltage signals need to be applied to prevent the pole dead logic from converting to 3-pole tripping

To test the first three-phase auto-reclose cycle, set cell [0F11: COMMISSION TESTS, Test Auto-reclose] to '**3 Pole Test**'. The relay will perform a trip/reclose cycle. Repeat this operation to test the subsequent three-phase auto-reclose cycles.

Check all output relays used for circuit breaker tripping and closing, blocking other devices, etc. operate at the correct times during the trip/close cycle.

The auto-reclose cycles for single phase trip conditions can be checked one at a time by sequentially setting cell [0F11: COMMISSION TESTS, Test Auto-reclose] to '**Pole A Test**', '**Pole B Test**' and '**Pole C Test**'.

8 END-TO-END COMMUNICATION TESTS (INTERMICOM ONLY)

If InterMiCOM protection signaling is being used, end-to-end testing is required. If not, skip to section 9.

In section 6 InterMiCOM communications loopbacks were applied to enable completion of the local end tests. In this section any loopbacks are removed and, if possible, satisfactory communications between line ends of the MiCOM relays in the scheme will be confirmed.

Note	*End-to-end communication requires the provision of a working telecommunication channel between line ends (which may be a multiplexed link or may be a direct connection). If the telecommunication channel is not available, it will not be possible to establish end-to end communication. Nonetheless unless otherwise directed by local operational practice, the instructions in section 8 should be followed such that the scheme is ready for full operation when the telecommunications channels becomes available.*
Note	*The trip circuit should remain isolated during these checks to prevent accidental operation of the associated circuit breaker.*

8.1 MODEM InterMiCOM

If MODEM InterMiCOM is being used, the end-to-end tests need to be performed. If not, skip to section 8.2.

8.1.1 Local End Configuration

Check that the [1520 Ch Statistics] and [1540 Ch Diagnostics] cells are set to visible. Use the statistics and diagnostics cells to check that the loopback communication remained healthy throughout the testing and that good messages are being received.

Check that the [1510 Source Address] and the [1511 Receive Address] are different, corresponding to the complimentary pair at the remote end as required by the application. Set the [1550 Loopback Mode] to disabled. The InterMiCOM communications should fail.

Remove the physical loopback connection that was made in section 6.1.1 and restore the communications link to its operational connection.

Observe that the LCD alarm message, “**IM Loopback**” and corresponding amber Alarm LED indication are not present.

8.1.2 Remote End Configuration

Repeat section 8.1.1 at the remote end (if not already done). If the remote end is not actively communicating, then a comprehensive test cannot be performed until the two ended system is established.

8.1.3 Verify End-to-End Communication

8.1.3.1 Verify Operational Link

If the communications link is operational then at either end the channel diagnostics (cells 1541 - 1545) should indicate ‘**OK**’.

8.1.3.2 Verify Pattern Transmission

Check that the [1502 IM Output Status] cell pattern at the local relay matches with the [1501 IM Input Status] at the remote end and vice versa.

8.1.3.3 Check Data Received Counters

The Rx count for Direct, Permissive and Blocking signals (subject to setting) will rise rapidly in proportion to Baud rate setting, whilst the Rx count for “**NewData**” and “**Errored**” and the percentage of “**Lost Messages**” must remain close to zero.

8.1.3.4 Statistics Check

Reset the InterMiCOM statistics [1531 Reset Statistics] and record the number of good messages (Direct, Permissive, Blocking) and the number of errored messages (NewData, Errored, Lost Messages) after a minimum period of 1 hour. Check that the ratio of errored/good messages is better than 10-4.

8.2 Fiber InterMiCOM^{64}

If InterMiCOM is being used, the end-to-end tests must be performed. If not, skip to section 9.

8.2.1 Remove local loopbacks

As well as removing the loopback test, this section checks that all wiring and optical fibers are reconnected. If P592 or P593 interface units are installed the application-specific settings will also be applied.

Check the alarm records to ensure that no communications failure alarms have occurred whilst the loopback test has been in progress.

Set cell [0F15 Test Mode] to ‘**Disabled**’.

Set cell [0F13 Loopback Mode] to ‘**Disabled**’.

Restore the communications channels as per the appropriate sub-section below.

8.2.1.1 Direct Fiber and C37.94 Connections

In section 6.2, most of the required optical signal power levels were measurements were taken. If all signaling uses P59x interface units, then no further measurements are required. If direct fiber or C37.94 communications are used then it will be necessary to make further measurements.

8.2.1.1.1 Direct Fiber Connections

It is necessary to check the optical power level received from the remote relay(s).

Remove the loopback test fiber(s) and at both ends of each channel used, reconnect the fiber optic cables for communications between relays, ensuring correct placement.

⚠

Warning	**When connecting or disconnecting optical fibers care should be taken not to look directly into the transmit port or end of the optical fibers.**

For each channel fitted, in turn, remove the fiber connecting to the optical receiver (RX) and, using an optical power meter measure the strength of the signal received from the remote relay. The measurements should be within the values shown in the tables below:

Relays Manufactured Pre April 2008	850nm multi-mode	1300nm multi-mode	1300nm single-mode
Maximum Transmitter Power (Average Value)	**-16.8dBm**	**-6dBm**	**-6dBm**
Minimum Transmitter Power (Average Value)	-25.4dBm	-49dBm	-49dBm

Relays Manufactured Post April 2008	850nm multi-mode	1300nm multi-mode	1300nm single-mode
Maximum Transmitter Power (Average Value)	**-16.8dBm**	**-7dBm**	**-7dBm**
Minimum Transmitter Power (Average Value)	-25.4dBm	-37dBm	-37dBm

Record the received power level(s).

Reconnect the fiber(s) to the MiCOM receiver(s).

8.2.1.1.2 Fiber Connections to C37.94

It is necessary to check the optical power level received from the MiCOM at the C37.94 multiplexer, as well as that received by the MiCOM from the C37.94 multiplexer.

Remove the loopback test fibers and at both ends of each channel used, reconnect the fiber optic cables for communications between relays and the C37.94 compatible multiplexer, ensuring correct placement.

Warning **When connecting or disconnecting optical fibers care should be taken not to look directly into the transmit port or end of the optical fibers.**

In a similar manner to that described in section 8.2.1.1.1, check that the value received from the MiCOM at the C37.94 multiplexer, as well as that received by the MiCOM from the C37.94 multiplexer are in the range presented in the table below:

Maximum Transmitter Power (Average Value)	-16.8dBm
Minimum Transmitter Power (Average Value)	-25.4dBm

Record the received power level(s).

Reconnect the fiber(s).

8.2.1.2 Communications using P591 Interface Units

Return to the P591 units.

Warning **Ensure that all external wiring that has been removed to facilitate testing is replaced in accordance with the relevant connection diagram or scheme diagram.**

If applicable, replace the secondary front cover on the P591 units.

8.2.1.3 Communications using P592 Interface Units

Return to the P592 units.

Warning **Ensure that all external wiring that has been removed to facilitate testing is replaced in accordance with the relevant connection diagram or scheme diagram.**

Set the ‘**V.35 LOOPBACK**’ switch to the ‘**0**’ position.

Set the ‘**CLOCK SWITCH**’, ‘**DSR**’, ‘**CTS**’ and ‘**DATA RATE**’ DIL switches on each unit to the positions required for the specific application and ensure the ‘**OPTO LOOPBACK**’ switch is in the ‘**0**’ position.

If applicable, replace the secondary front cover on the P592 units.

8.2.1.4 Communications using P593 Interface Units

Return to the P593 units.

Warning **Ensure that all external wiring that has been removed to facilitate testing is replaced in accordance with the relevant connection diagram or scheme diagram.**

Set the ‘**X.21 LOOPBACK**’ switch to the ‘**OFF**’ position and ensure the ‘**OPTO LOOPBACK**’ switch is also in the ‘**OFF**’ position.

If applicable, replace the secondary front cover on the P593 units.

8.2.2 Remote loopback Removal

8.2.2.1 Remove Loopbacks at Remote Terminal Connected to Channel 1

Repeat sections 8.2.1.1 to 8.2.1.4 as necessary at the remote end relay connected to channel 1.

8.2.2.2 Remove Loopbacks at Remote Terminal Connected to Channel 2

Repeat sections 8.2.1.1 to 8.2.1.4 as necessary at the remote end relay connected to channel 2.

8.2.3 Verify Communications between Relays

Reset any alarm indications and check that no further communications failure alarms are raised. Using the following cells in the [MEASUREMENTS 4] to check that the communications channel(s) is(are) working correctly:

[0513 Ch1 No. Vald Mess]	should be incrementing for healthy channel 1
[0514 Ch1 No. Err Mess]	should be zero healthy channel 1
[0518 Ch2 No. Vald Mess]	should be incrementing for healthy channel 2
[0519 Ch2 No. Err Mess]	should be zero for healthy channel 2

Clear the statistics and record the number of valid messages and the number of errored messages after a minimum period of 1 hour. Check that the ratio of errored/good messages is better than 10^{-4}. Record the measured message propagation delays for channel 1, and channel 2 (if fitted).

9 END-TO-END SCHEME TESTS

If an external signaling channel is being employed to provide aided scheme signalling (i.e. an aided protection scheme is being realised without InterMiCOM protection signalling, it should be tested. If only basic schemes are being used, or if InterMiCOM is being used to realise the schemes, skip to section 11.

9.1 Signaling Channel Check

This section aims to check that the signaling channel is able to transmit the ON/OFF signals used in aided schemes between the remote line ends. Before testing, check that the channel is healthy (for example, if a power line carrier link is being used, it may not be possible to perform the tests until the protected circuit is live and has in-service). If the channel tests must be postponed, make a note to perform them as a part of the "**ON-LOAD CHECKS**" in section 11 of these Commissioning Instructions.

9.1.1 Aided Scheme 1

If Aided Scheme 1 is enabled, it must be tested. This is achieved by operating output contacts as in section 5.2.7 to mimic the relay sending an aided channel signal.

Note: *For these tests, it will be necessary that an engineer is present at both ends of the line - at the local end to send aided signals, and at the remote end to observe that the signals have been received as required. A telephone link between the two commissioning engineers will be necessary, to allow conversation.*

Put the relay in test mode by setting cell [0F0D: COMMISSION TESTS, Test Mode] to '**Blocked**'.

Record which contact is assigned as the *Signal Send 1* output. Select this output contact as the one to test. And advise the remote end engineer that the contact is about to be tested.

9.1.1.1 Remote End Preparation to Observe Channel Arrival

At the remote end, the engineer must confirm the assignment of the Monitor Bits in the COMMISSION TESTS column in the menu, in order to be able to see the aided channel on arrival. Scroll down and ensure cells are set: [0F05: Monitor Bit 1] to 493, and [0F09: Monitor Bit 5] to 507. In doing so, cell [0F03: Test Port Status] will appropriately set or reset the bits that now represent Aided 1 Scheme Receive (DDB #493), and Aided 2 Scheme Receive (DDB #507), with the rightmost bit representing Aided Channel 1. From now on the remote end engineer should monitor the indication of [0F03: Test Port Status].

9.1.1.2 Application of the Test

At the local end, to operate the output relay set cell [0F0F: COMMISSION TESTS, Contact Test] to '**Apply Test**'.

Reset the output relay by setting cell [0F0F: COMMISSION TESTS, Contact Test] to '**Remove Test**'.

Note *It should be ensured that thermal ratings of anything connected to the output relays during the contact test procedure are not exceeded by the associated output relay being operated for too long. It is therefore advised that the time between application and removal of the contact test is kept to the minimum.*

Check with the engineer at the remote end that the Aided Channel 1 signal did change state as expected. The Test Port Status should have responded as in the table below:

DDB No.				**507**				**493**
Monitor Bit	8	7	6	5	4	3	2	1
Contact Test OFF	X	X	X	X	X	X	X	0
Contact Test Applied (ON)	X	X	X	X	X	X	X	1
Test OFF	X	X	X	X	X	X	X	0

Note: *"**x**" = Wildcard/denotes don't care*

Return the relay to service by setting cell [0F0D: COMMISSION TESTS, Test Mode] to '**Disabled**'.

9.1.1.3 Channel cheCk in the Opposite Direction

Repeat the aided scheme 1 test procedure, but this time to check that the channel responds correctly when keyed from the remote end. The remote end commissioning engineer should perform the contact test, with the Monitor Option observed at the local end.

9.1.2 Aided scheme 2

If applicable, now repeat the test for Aided Channel 2. Repeat as per 9.1.1 above, checking that Monitor Bit 5 responds correctly for channel transmission in both directions (from the local end to the remote end, and vice versa).

Return the relay to service by setting cell [0F0D: COMMISSION TESTS, Test Mode] to '**Disabled**'.

10 MODEM INTERMICOM SCHEME TESTING

If the aided scheme tests described in section 7.2 could not be carried out for a scheme using MODEM InterMiCOM signaling due to lack of access to the internal signal, they will need to be checked here. The principles are the same as those described in sections 7.2.3, 7.2.4, 7.2.7 and 7.2.9, but in order to generate the correct conditions to stimulate the appropriate signaling commands and responses, synchronous generation of the fault scenarios at each end of the protected line will be required.

11 ON-LOAD CHECKS

The objectives of the on-load checks are to:

- Confirm the external wiring to the current and voltage inputs is correct
- Check the polarity of the line current transformers at each end is consistent
- Directionality check for distance (or delta directional) elements

However, these checks can only be carried out if there are no restrictions preventing the energization of the plant being protected and the other P443/P446 relays in the group have been commissioned.

Remove all test leads, temporary shorting leads, etc. and replace any external wiring that has been removed to allow testing.

Warning **If it has been necessary to disconnect any of the external wiring from the relay in order to perform any of the foregoing tests, it should be ensured that all connections are replaced in accordance with the relevant external connection or scheme diagram.**

11.1 Confirm Current and Voltage Transformer Wiring

11.1.1 Voltage Connections

Caution **Using a multimeter measure the voltage transformer secondary voltages to ensure they are correctly rated. Check that the system phase rotation is correct using a phase rotation meter.**

Compare the values of the secondary phase voltages with the relays measured values, which can be found in the MEASUREMENTS 1 menu column.

Voltage	Cell in MEASUREMENTS 1 Column (02)	Corresponding VT Ratio in 'VT and CT RATIO' Column (0A) of Menu)
VAB	[0214 : VAB Magnitude]	[0A01 : Main VT Primary] [0A02 : Main VT Secondary]
VBC	[0216 : VBC Magnitude]	
VCA	[0218 : VCA Magnitude]	
VAN	[021A : VAN Magnitude]	
VBN	[021C : VBN Magnitude]	
VCN	[021^{E} : VCN Magnitude]	
VCHECKSYNC.	[022E: (CB1) CS Volt Mag]	[0A03 : (CB1) CS VT Prim'y] [0A04 : (CB1) CS VT Sec'y]
CB2 VCHECKSYNC.	[024C: CB2 CS Volt Mag] (P446 only)	[0A05 : CB2 CS VT Prim'y] [0A06 : CB2 CS VT Sec'y]

Table 15 - Measured voltages and VT ratio settings

If cell [0D02: MEASURE'T. SETUP, Local Values] is set to '**Secondary**', the values displayed on the relay LCD or a portable PC connected to the front EIA(RS)232 communication port should be equal to the applied secondary voltage. The values should be within 1% of the applied secondary voltages. However, an additional allowance must be made for the accuracy of the test equipment being used.

If cell [0D02: MEASURE'T. SETUP, Local Values] is set to '**Primary**', the values displayed should be equal to the applied secondary voltage multiplied the corresponding voltage transformer ratio set in the '**CT & VT RATIOS**' menu column (see Table 12). Again the values should be within 1% of the expected value, plus an additional allowance for the accuracy of the test equipment being used.

11.1.2 Current Connections

Measure the current transformer secondary values for each input using a multimeter connected in series with the corresponding relay current input.

Check that the current transformer polarities are correct by measuring the phase angle between the current and voltage, either against a phase meter already installed on site and known to be correct or by determining the direction of power flow by contacting the system control center.

Ensure the current flowing in the neutral circuit of the current transformers is negligible.

Compare the values of the secondary phase currents and phase angle with the relay's measured values, which can be found in the MEASUREMENTS 1 menu column.

If cell [0D02: MEASURE'T. SETUP, Local Values] is set to '**Secondary**', the currents displayed on the LCD or a portable PC connected to the front EIA(RS)232 communication port of the relay should be equal to the applied secondary current. The values should be within 1% of the applied secondary currents. However, an additional allowance must be made for the accuracy of the test equipment being used.

If cell [0D02: MEASURE'T. SETUP, Local Values] is set to '**Primary**', the currents displayed on the relay should be equal to the applied secondary current multiplied by the corresponding current transformer ratio set in '**CT & VT RATIOS**' menu column . Again the values should be within 1% of the expected value, plus an additional allowance for the accuracy of the test equipment being used.

11.2 On-Load Directional Test

This test is important to ensure that directionalized overcurrent and fault locator functions have the correct forward/reverse response to fault and load conditions.

Firstly the actual direction of power flow on the system must be ascertained, using adjacent instrumentation or protection already in-service, or a knowledge of the prevailing network operation conditions.

- For load current flowing in the Forward direction - i.e. power export to the remote line end, cell [0301: MEASUREMENTS 2, A Phase Watts] should show **positive** power signing
- For load current flowing in the Reverse direction - i.e. power import from the remote line end, cell [0301: MEASUREMENTS 2, A Phase Watts] should show **negative** power signing

Note *The check above applies only for Measurement Modes 0 (default), and 2. This should be checked in [0D05: MEASURE'T. SETUP, Measurement Mode = 0 or 2]. If measurement modes 1 or 3 are used, the expected power flow signing would be opposite to that shown in the bullets above.*

In the event of any uncertainty, check the phase angle of the phase currents with respect to their phase voltage.

11.3 Signaling Channel Check (if not Already Completed)

If the aided scheme signaling channel(s) was/were not tested already in section 9 they should be tested now. This test may be avoided only with the agreement of the customer, or if only the basic scheme is used.

12 FINAL CHECKS

The tests are now complete.

Warning	**Remove all test or temporary shorting leads, etc. If it has been necessary to disconnect any of the external wiring from the relay in order to perform the wiring verification tests, it should be ensured that all connections (wiring, fuses and links) are replaced in accordance with the relevant external connection or scheme diagram.**

Ensure that the relay has been restored to service by checking that cell [0F0D: COMMISSION TESTS, Test Mode] and [0F12: COMMISSION TESTS, Static Test] are set to '**Disabled**'.

The settings applied should be carefully checked against the required application-specific settings to ensure that they are correct, and have not been mistakenly altered during testing.

There are two methods of checking the settings:

- Extract the settings from the relay using a portable PC running the appropriate software via the front EIA(RS)232 port, located under the bottom access cover, or rear communications port (with a KITZ protocol converter connected). Compare the settings transferred from the relay with the original written application-specific setting record. (For cases where the customer has only provided a printed copy of the required settings but a portable PC is available).
- Step through the settings using the relay's operator interface and compare them with the original application-specific setting record. Ensure that all protection elements required have been ENABLED in the CONFIGURATION column.

If the relay is in a new installation or the circuit breaker has just been maintained, the circuit breaker maintenance and current counters should be zero. These counters can be reset using cell [0609: CB CONDITION, Reset All Values]. If the required access level is not active, the relay will prompt for a password to be entered so that the setting change can be made.

If the menu language has been changed to allow accurate testing it should be restored to the customer's preferred language.

If a P991/MMLG test block is installed, remove the P992/MMLB test plug and replace the cover so that the protection is put into service.

Ensure that all event records, fault records, disturbance records, alarms, LEDs and communications statistics have been reset before leaving the relay.

If applicable, replace the secondary front cover on the relay.

13 COMMISSIONING TEST RECORD

Date: ______________________ Engineer: ______________________

Station: Circuit: ______________________

System Frequency: ______________ Hz

VT Ratio: __________ / ______ V CT Ratio (tap in use): __________ / ______ A

13.1 Front Plate Information

Distance protection relay	**P44____**
Model number	
Serial number	
Rated current In	1A ☐ 5A ☐
Rated voltage Vn	
Auxiliary voltage Vx	

13.2 Test Equipment Used

This section should be completed to allow future identification of protective devices that have been commissioned using equipment that is later found to be defective or incompatible but may not be detected during the commissioning procedure.

Injection test set	Model: Serial No:	
Optical power meter	Model: Serial No:	
Phase angle meter	Model: Serial No:	
Phase rotation meter	Model: Serial No:	
Insulation tester	Model: Serial No:	
Setting software:	Type: Version:	

		*Delete as appropriate
	Have all relevant safety instructions been followed?	Yes* ☐ No* ☐
5	**Product checks**	
5.1	**With the relay de-energized**	
5.1.1	Visual inspection	
	Relay damaged?	Yes* ☐ No* ☐
	Rating information correct for installation?	Yes* ☐ No* ☐
	Case earth installed?	Yes* ☐ No* ☐
5.1.2	Current transformer shorting contacts close?	Yes* ☐ No* ☐ Not checked* ☐
5.1.3	Insulation resistance >100MΩ at 500V dc	Yes* ☐ No* ☐ Not tested* ☐
5.1.4	External wiring	
	Wiring checked against diagram?	Yes* ☐ No* ☐
	Test block connections checked?	Yes* ☐ No* ☐ N/A* ☐
5.1.5	Watchdog contacts (auxiliary supply off)	
	Terminals 11 and 12 Contact closed?	Yes* ☐ No* ☐
	Terminals 13 and 14 Contact open?	Yes* ☐ No* ☐
5.1.6	Measured auxiliary supply	_____ V ac/dc*
5.2	**With the relay energized**	
5.2.1	Watchdog contacts (auxiliary supply on)	
	Terminals 11 and 12 Contact open?	Yes* ☐ No* ☐
	Terminals 13 and 14 Contact closed?	Yes* ☐ No* ☐
5.2.2	LCD front panel display	
	LCD contrast setting used	_____
5.2.3	Date and time	
	Clock set to local time?	Yes* ☐ No* ☐
	Time maintained when auxiliary supply removed?	Yes* ☐ No* ☐

***Delete as appropriate**

5.2.4	Light emitting diodes	
5.2.4.1	Alarm (yellow) LED working?	Yes* ☐ No* ☐
	Out of service (yellow) LED working?	Yes* ☐ No* ☐
5.2.4.3	All 18 programmable LEDs working?	Yes* ☐ No* ☐
5.2.5	Field supply voltage	
	Value measured between terminals 7 and 9	_____ V dc
5.2.6	Input opto-isolators	
	Opto input 1 working?	Yes* ☐ No* ☐
	Opto input 2 working?	Yes* ☐ No* ☐
	Opto input 3 working?	Yes* ☐ No* ☐
	Opto input 4 working?	Yes* ☐ No* ☐
	Opto input 5 working?	Yes* ☐ No* ☐
	Opto input 6 working?	Yes* ☐ No* ☐
	Opto input 7 working?	Yes* ☐ No* ☐
	Opto input 8 working?	Yes* ☐ No* ☐
	Opto input 9 working?	Yes* ☐ No* ☐
	Opto input 10 working?	Yes* ☐ No* ☐
	Opto input 11 working?	Yes* ☐ No* ☐
	Opto input 12 working?	Yes* ☐ No* ☐
	Opto input 13 working?	Yes* ☐ No* ☐
	Opto input 14 working?	Yes* ☐ No* ☐
	Opto input 15 working?	Yes* ☐ No* ☐
	Opto input 16 working?	Yes* ☐ No* ☐
	Opto input 17 working?	Yes* ☐ No* ☐ N/A* ☐
	Opto input 18 working?	Yes* ☐ No* ☐ N/A* ☐
	Opto input 19 working?	Yes* ☐ No* ☐ N/A* ☐
	Opto input 20 working?	Yes* ☐ No* ☐ N/A* ☐
	Opto input 21 working?	Yes* ☐ No* ☐ N/A* ☐
	Opto input 22 working?	Yes* ☐ No* ☐ N/A* ☐
	Opto input 23 working?	Yes* ☐ No* ☐ N/A* ☐
	Opto input 24 working?	Yes* ☐ No* ☐ N/A* ☐
	Opto input 25 working?	Yes* ☐ No* ☐ N/A* ☐

			***Delete as appropriate**
	Opto input 26	working?	Yes* ☐ No* ☐ N/A* ☐
	Opto input 27	working?	Yes* ☐ No* ☐ N/A* ☐
	Opto input 28	working?	Yes* ☐ No* ☐ N/A* ☐
	Opto input 29	working?	Yes* ☐ No* ☐ N/A* ☐
	Opto input 30	working?	Yes* ☐ No* ☐ N/A* ☐
	Opto input 31	working?	Yes* ☐ No* ☐ N/A* ☐
	Opto input 32	working?	Yes* ☐ No* ☐ N/A* ☐
5.2.7	Output relays		
	Relay 1	working?	Yes* ☐ No* ☐
	Relay 2	working?	Yes* ☐ No* ☐
	Relay 3	working?	Yes* ☐ No* ☐
	Relay 4	working?	Yes* ☐ No* ☐
	Relay 5	working?	Yes* ☐ No* ☐
	Relay 6	working?	Yes* ☐ No* ☐
	Relay 7	working?	Yes* ☐ No* ☐
	Relay 8	working?	Yes* ☐ No* ☐
	Relay 9	working?	Yes* ☐ No* ☐
	Relay 10	working?	Yes* ☐ No* ☐
	Relay 11	working?	Yes* ☐ No* ☐
	Relay 12	working?	Yes* ☐ No* ☐
	Relay 13	working?	Yes* ☐ No* ☐
	Relay 14	working?	Yes* ☐ No* ☐
	Relay 15	working?	Yes* ☐ No* ☐
	Relay 16	working?	Yes* ☐ No* ☐
	Relay 17	working?	Yes* ☐ No* ☐
	Relay 18	working?	Yes* ☐ No* ☐
	Relay 19	working?	Yes* ☐ No* ☐
	Relay 20	working?	Yes* ☐ No* ☐
	Relay 21	working?	Yes* ☐ No* ☐ N/A* ☐
	Relay 22	working?	Yes* ☐ No* ☐ N/A* ☐
	Relay 23	working?	Yes* ☐ No* ☐ N/A* ☐
	Relay 24	working?	Yes* ☐ No* ☐ N/A* ☐
	Relay 25	working?	Yes* ☐ No* ☐ N/A* ☐
	Relay 26	working?	Yes* ☐ No* ☐ N/A* ☐

***Delete as appropriate**

	Relay 27 working?	Yes* ☐ No* ☐ N/A* ☐
	Relay 28 working?	Yes* ☐ No* ☐ N/A* ☐
	High Break Relay 9 External wiring polarity check?	Yes* ☐ No* ☐ N/A* ☐
	High Break Relay 10 External wiring polarity check?	Yes* ☐ No* ☐ N/A* ☐
	High Break Relay 11 External wiring polarity check?	Yes* ☐ No* ☐ N/A* ☐
	High Break Relay 12 External wiring polarity check?	Yes* ☐ No* ☐ N/A* ☐
	High Break Relay 13 External wiring polarity check?	Yes* ☐ No* ☐ N/A* ☐
	High Break Relay 14 External wiring polarity check?	Yes* ☐ No* ☐ N/A* ☐
	High Break Relay 15 External wiring polarity check?	Yes* ☐ No* ☐ N/A* ☐
	High Break Relay 16 External wiring polarity check?	Yes* ☐ No* ☐ N/A* ☐
	High Break Relay 17 External wiring polarity check?	Yes* ☐ No* ☐ N/A* ☐
	High Break Relay 18 External wiring polarity check?	Yes* ☐ No* ☐ N/A* ☐
	High Break Relay 19 External wiring polarity check?	Yes* ☐ No* ☐ N/A* ☐
	High Break Relay 20 External wiring polarity check?	Yes* ☐ No* ☐ N/A* ☐
	High Break Relay 21 External wiring polarity check?	Yes* ☐ No* ☐ N/A* ☐
	High Break Relay 22 External wiring polarity check?	Yes* ☐ No* ☐ N/A* ☐
	High Break Relay 23 External wiring polarity check?	Yes* ☐ No* ☐ N/A* ☐
	High Break Relay 24 External wiring polarity check?	Yes* ☐ No* ☐ N/A* ☐
5.2.8	Communication standard	Courier* ☐ IEC60870-5-103* ☐ DNP3.0* ☐
	Communications established?	Yes* ☐

			***Delete as appropriate**
			No* ☐
	Protocol converter tested?		Yes* ☐ No* ☐ N/A* ☐
5.2.9	Second rear communication interface		K-Bus* ☐ EIA485* ☐ EIA232* ☐
	Communications established?		Yes* ☐ No* ☐
5.2.10	Current inputs		
	Displayed current		Primary* ☐ Secondary* ☐
	Phase CT ratio		_____ N/A* ☐
	Mutual CT ratio		_____ N/A* ☐
	Input CT	Applied Value	Displayed Value
	IA	_____ A	_____ A
	IB	_____ A	_____ A
	IC	_____ A	_____ A
	IA2	_____ A	_____ A N/A* ☐
	IB2	_____ A	_____ A N/A* ☐
	IC2	_____ A	_____ A N/A* ☐
	ISEF	_____ A N/A* ☐	_____ A N/A* ☐
	IM	_____ A N/A* ☐	_____ A N/A* ☐
5.2.11	Voltage inputs		
	Displayed voltage		Primary* ☐ Secondary* ☐
	Main VT ratio		_____ N/A* ☐
	C/S VT ratio		_____ N/A* ☐
	Input VT	Applied Value	Displayed Value
	VAN	_____ V	_____ V
	VBN	_____ V	_____ V
	VCN	_____ V	_____ V
	CS Voltage	_____ V N/A* ☐	_____ V
	CB2 CS Voltage	_____ V N/A* ☐	_____ V
6	InterMiCOM communications loopback		
6.1	MODEM InterMiCOM		
	InterMiCOM hardware status OK?		Yes* ☐ No* ☐

		***Delete as appropriate**
6.1.1	Loopback mode set to external?	Yes* ☐ No* ☐
	Loopback connection made?	Yes* ☐ No* ☐
	Loopback connection location	
	IM Loopback message and LED indication?	Yes* ☐ No* ☐
	IM Loopback status OK?	Yes* ☐ No* ☐
6.1.1.1	Test pattern set	
	IM output status received	
	IM input status all zero?	Yes* ☐ No* ☐
6.1.1.2	InterMiCOM channel diagnostics	
	Data CD status OK?	Yes* ☐ No* ☐
	Frame sync status OK?	Yes* ☐ No* ☐
	Message status OK?	Yes* ☐ No* ☐
	Channel status OK?	Yes* ☐ No* ☐
6.1.1.3	Channel failure indication for broken channel?	Yes* ☐ No* ☐
	Channel status OK for restored loopback?	Yes* ☐ No* ☐
6.2	InterMiCOM^{64} fiber communications	
6.2.1	Test loopback set to external?	Yes* ☐
6.2.1.1	Channel 1 transmit power level	_____ dBm
6.2.1.2	Channel 2 transmit power level	_____ dBm N/A* ☐
6.2.2	Fiber optic configuration	
	Type of fiber optic connection for channel 1	Direct* ☐ C37.94* ☐ P591* ☐ P592* ☐ P593* ☐
	Fiber connections made with P59x unit on Ch 1?	Yes* ☐ N/A* ☐
	Type of fiber optic connection for channel 2	Direct* ☐ C37.94* ☐ P591* ☐ P592* ☐ P593* ☐ N/A* ☐
	Fiber connections made with P59x unit on Ch 2?	Yes* ☐ N/A* ☐
6.2.3	Fiber loopback connection made for ‘**Direct**’ or	Yes* ☐ N/A* ☐

		*Delete as appropriate
	‘**C37.94**’ on Ch 1?	
	Fiber loopback connection made for ‘**Direct**’ or ‘**C37.94**’ on Ch 2?	Yes* ☐ N/A* ☐
6.2.n	Communications using P59x units: n=4 for P591 n=5 for P592 n=6 for P593 Apply to MiCOM Ch1 and/or Ch2 as appropriate	
6.2.n.1	Visual inspection (P59x units only) Ch1	
	Ch 1 unit damaged?	Yes* ☐ No* ☐ N/A* ☐
	Ch 1 rating information correct?	Yes* ☐ No* ☐ N/A* ☐
	Ch 1 earthed?	Yes* ☐ No* ☐ N/A* ☐
6.2.n.2	Insulation resistance (P59x units only)	
	Ch 1 unit	Yes* ☐ No* ☐ Not Tested ☐ N/A*
6.2.n.3	External wiring (P59x units only)	
	Ch 1 unit checked against diagram?	Yes* ☐ No* ☐ N/A* ☐
6.2.n.4	Measured auxiliary supply (P59x units only)	
	Ch 1 unit	_____ V dc/ac N/A* ☐
6.2.n.5	Light emitting diodes (P59x units only)	
	Ch 1 unit LED’s working?	Yes* ☐ No* ☐ N/A* ☐
6.2.n.6	P59x optical received signal level	
	Signal strength received by P59x connected to Ch 1	dBm N/A* ☐
6.2.n.7	P59x loopback configured?	Yes* ☐ N/A* ☐
	Signal strength received by P59x connected to Ch 1	dBm N/A* ☐
6.2.n.8	Signal strength transmitted by P59x on Ch 1	dBm N/A* ☐

		***Delete as appropriate**
6.2.n.9	MiCOM optical received signal level Ch 1 from P59x	dBm N/A* ☐
6.2.n.1	Visual inspection (P59x units only) Ch2	
	Ch 2 unit damaged?	Yes* ☐ No* ☐ N/A* ☐
	Ch 2 rating information correct?	Yes* ☐ No* ☐ N/A* ☐
	Ch 2 earthed?	Yes* ☐ No* ☐ N/A* ☐
6.2.n.2	Insulation resistance (P59x units only)	
	Ch 2 unit	Yes* ☐ No* ☐ Not Tested ☐ N/A*
6.2.n.2	External wiring (P59x units only)	
	Ch 2 unit checked against diagram?	Yes* ☐ No* ☐ N/A* ☐
6.2.n.4	Measured auxiliary supply (P59x units only)	
	Ch 2 unit	______ V dc/ac N/A* ☐
6.2.n.5	Light emitting diodes (P59x units only)	
	Ch 2 unit LED’s working?	Yes* ☐ No* ☐ N/A* ☐
6.2.n.6	P59x optical received signal level	
	Signal strength received by P59x connected to Ch 2	dBm N/A* ☐
6.2.n.7	P59x loopback configured?	Yes* ☐ N/A* ☐
	Signal strength received by P59x connected to Ch 2	dBm N/A* ☐
6.2.n.8	Signal strength transmitted by P59x on Ch 2	dBm N/A* ☐
6.2.n.9	MiCOM optical received signal level Ch2 from P59x	dBm N/A* ☐
6.2.7	IM64 loopback test	
	IM64 test pattern set	
	IM64 Rx status observed	

		***Delete as appropriate**
7	Setting checks	
7.1	Application-specific function settings applied?	Yes* ☐ No* ☐
	Application-specific programmable scheme logic settings applied?	Yes* ☐ No* ☐ N/A* ☐
	Relay power-off and on if IM64 Comms Mode changed?	Yes* ☐ N/A* ☐
7.1.1	InterMiCOM Loopback Mode and Test Pattern configured?	Yes* ☐ N/A* ☐
7.1.2	InterMiCOM statistics reset?	Yes* ☐ N/A* ☐
7.2	Injection testing - distance zones	
7.2.1	Elements to be re-enabled after testing (mark any that have been temporarily disabled)	Delta Directional ☐ Earth Fault ☐ Overcurrent ☐ DEF ☐ CB Fail ☐ N/A* ☐
7.2.1.2	Zone 1 reach check – impedance at trip	_____ Ω Not measured* ☐
7.2.1.3	Zone 2 reach check – impedance at trip	_____ Ω Not measured* ☐
7.2.1.4	Zone 3 reach check – impedance at trip	_____ Ω Not measured* ☐
7.2.1.5	Zone 4 reach check – impedance at trip	_____ Ω Not measured* ☐
7.2.1.6	Zone P reach check – impedance at trip	_____ Ω Not measured* ☐
7.2.1.7	Resistive reach	
	Visual inspection	
	Phase & ground element resistive reach settings are correct?	Yes* ☐ No* ☐
7.2.1.8	Load blinder	
	Visual inspection	
	Load blinder settings are correct?	Yes* ☐ No* ☐

		***Delete as appropriate**
		N/A* ☐
	Load blinder angle applied	_____° N/A* ☐
7.2.2.1	Distance phase A contact routing OK?	Yes* ☐ No* ☐
	Distance phase A trip time	_____ ms
7.2.2.2	Distance phase B contact routing OK?	Yes* ☐ No* ☐
	Distance phase B trip time	_____ ms
7.2.2.3	Distance phase C contact routing OK?	Yes* ☐ No* ☐
	Distance phase C trip time	_____ ms
	Average trip time, phases A, B and C	_____ ms
7.2.2.4	Time delay settings tZ1 Ph, and tZ2 – tZ4	
	Visual inspection	
	Time delay settings are correct?	Yes* ☐ No* ☐
7.2.3	Distance protection scheme testing	
7.2.3.1	Scheme trip zone 1 extension scheme	
	No trip for fault with reset Z1X energized	Yes* ☐ No* ☐
	Trip time with reset Z1X de-energized	_____ ms
7.2.3.2	Scheme trip permissive schemes (PUR/POR)	
	Trip time with signal receive energized	_____ ms
7.2.3.3	Scheme trip blocking scheme	
	No trip for fault with signal receive energized	Yes* ☐ No* ☐
	Trip time with signal receive de-energized	_____ ms
7.2.3.4	Signal send test for permissive schemes	
	Signal send operate time	_____ ms
7.2.3.5	Signal send blocking schemes	
	Signal send operate time	_____ ms
7.2.4	Scheme timer settings	
	Visual inspection	
	Time delays settings are correct?	Yes* ☐ No* ☐

		*Delete as appropriate
	All disabled elements which were noted/circled previously are restored?	Yes* ☐ No* ☐
0	Delta directional comparison	
	Elements to be re-enabled after testing (circle any that have been temporarily disabled)	Distance ☐ Earth Fault ☐ Overcurrent ☐ DEF ☐ CB Fail ☐ N/A* ☐
7.2.6.1	Directional comparison protection Phase A contact routing OK?	Yes* ☐ No* ☐
	Directional comparison protection Phase A trip time	_____ ms
7.2.6.2	Directional comparison protection Phase B contact routing OK?	Yes* ☐ No* ☐
	Directional comparison protection Phase B trip time	_____ ms
7.2.6.3	Directional comparison protection Phase C contact routing OK?	Yes* ☐ No* ☐
	Directional comparison protection phase C trip time	_____ ms
	Average trip time, phases A, B and C	_____ ms
7.2.7.1	Signal send test for permissive schemes	
	Signal send operate time	_____ ms
7.2.7.2	Signal send blocking schemes	
	Signal send operate time	_____ ms
	All disabled elements which were noted/circled previously are restored?	Yes* ☐ No* ☐
0	Injection testing - DEF aided scheme	
	Elements to be re-enabled after testing (mark any that have been temporarily disabled)	Delta Directional ☐ Distance ☐ Earth Fault ☐ Overcurrent ☐ CB Fail ☐

		***Delete as appropriate**
		N/A* ☐
7.2.8.2	DEF aided scheme trip time	_____ ms
7.2.9.1	DEF signal send time permissive scheme	_____ ms
7.2.9.2	DEF signal send time blocking scheme	_____ ms
	All disabled elements which were noted/circled previously are restored?	Yes* ☐ No* ☐
0	Out of step protection	
7.2.10.1	Predictive OST	Enabled* ☐ N/A* ☐
	Operated correctly?	Yes* ☐ No* ☐
	Operating time	_____ ms
7.2.10.2	OST	Enabled* ☐ N/A* ☐
	Operated correctly?	Yes* ☐ No* ☐
	Operating time	_____ ms
7.2.10.3	Predictive and OST	Enabled* ☐ N/A* ☐
	Operated correctly?	Yes* ☐ No* ☐
	Operating time	_____ ms
7.2.10.4	Tost timer test	
	Trip time	_____ ms
7.2.11	Back-up phase overcurrent protection	
	Elements to be re-enabled after testing (circle any that have been temporarily disabled)	Delta Directional ☐ Distance ☐ Earth Fault ☐ DEF ☐ CB Fail ☐ N/A* ☐
	Overcurrent type (set in cell [□>1 Direction])	Directional* ☐ Non-directional* ☐
	Applied voltage	_____ V/N/A*
	Applied current	_____ A

		***Delete as appropriate**
	Expected operating time	______ s
7.2.11.3	Measured operating time	______ s
	All disabled elements which were noted/circled previously are restored?	Yes* ☐ No* ☐
7.3	Trip and auto-reclose cycle checked	
	3 pole cycle tested?	Yes* ☐ No* ☐ N/A* ☐
	Pole A cycle tested?	Yes* ☐ No* ☐ N/A* ☐
	Pole B cycle tested?	Yes* ☐ No* ☐ N/A* ☐
	Pole C cycle tested?	Yes* ☐ No* ☐ N/A* ☐
8	END-TO-END COMMUNICATION TESTS (InterMiCOM only)	
8.1	MODEM InterMiCOM	
8.1.1	Local channel statistics and channel diagnostics visible?	Yes* ☐ No* ☐ N/A* ☐
	Local source address and receive address correct?	Yes* ☐ No* ☐ N/A* ☐
	Local operational connection restored?	Yes* ☐ No* ☐ N/A* ☐
	Local loopback indication absent?	Yes* ☐ No* ☐ N/A* ☐
8.1.2	Remote channel statistics and channel diagnostics visible?	Yes* ☐ No* ☐ N/A* ☐
	Remote source address and receive address correct?	Yes* ☐ No* ☐ N/A* ☐
	Remote operational connection restored?	Yes* ☐ No* ☐ N/A* ☐
	Remote loopback indication absent?	Yes* ☐ No* ☐ N/A* ☐
8.1.3	Verify end-to-end communications	
8.1.3.1	Local channel diagnostics OK?	
	Remote channel diagnostics OK?	
8.1.3.2	Local IM Output Status pattern	
	Remote IM Input Status pattern	
	Pattern match?	Yes* ☐ No* ☐ N/A* ☐
	Remote IM Output Status pattern	

		***Delete as appropriate**
	Local IM Input Status pattern	
	Pattern match?	Yes* ☐ No* ☐ N/A* ☐
8.1.3.3	Received data/error counters OK	
8.1.3.4	Statistics reset at (time)	____ : ____ : ____
	Statistics measured at (reset time + 1 hr minimum)	____ : ____ : ____
	Statistics measurements	
	Direct	
	Permissive	
	Blocking	
	NewData	
	Errorred	
	Lost Messages	
	Ratio : errored/good	
8.2	Fiber InterMiCOM	
	Any Ch 1 communication alarm?	Yes* ☐ No* ☐
	Any Ch 2 communication alarm?	Yes* ☐ No* ☐ N/A* ☐
	Restore Communications Channels	
8.2.1.1.1	Direct fiber connection	
	Optical received signal level Ch 1	_____ dBm N/A* ☐
	Optical received signal level Ch 2	_____ dBm N/A* ☐
8.2.1.1.2	Fiber connections to C37.94	
	Optical received signal level from C37.94 Ch 1	_____ dBm N/A* ☐
	Optical received signal level at C37.94 Ch 1	_____ dBm N/A* ☐
	Optical received signal level from C37.94 Ch 1	_____ dBm N/A* ☐
	Optical received signal level at C37.94 Ch 1	_____ dBm N/A* ☐
8.2.1.1 - 8.2.1.4	All local connections restored?	
	Local Ch 1	Yes* ☐ No* ☐
	Local Ch 2	Yes* ☐ No* ☐ N/A* ☐

		***Delete as appropriate**
	Application-specific settings applied? (P592 only)	
	Local Ch 1	Yes* ☐ No* ☐ N/A* ☐
	Local Ch 2	Yes* ☐ No* ☐ N/A* ☐
	Cover replaced? (P59x only)	
	Local Ch 1	Yes* ☐ No* ☐ N/A* ☐
	Local Ch 2	Yes* ☐ No* ☐ N/A* ☐
8.2.2.1	All connections restored at relay connected to Ch1?	Yes* ☐ No* ☐
8.2.2.2	All connections restored at relay connected to Ch2?	Yes* ☐ No* ☐ N/A* ☐
8.2.3	Verify communications between relays	
	Alarms reset?	Yes* ☐ No* ☐
	Ch 1 propagation time delay	_____ ms
	Ch 2 propagation time delay	_____ ms N/A* ☐
	Channel 1 valid message incrementing and errored messages zero?	
	Channel 2 valid message incrementing and errored messages zero?	
	Statistics reset at (time)	____ : ____ : ____
	Statistics measured at (reset time + 1 hr minimum)	____ : ____ : ____
	Statistics measurements	
	Ch 1 No. Valid Messages	
	Ch 1 No. Err Messages	
	Ch 1 Errored/Valid	
	Ch 1 Errored/Valid < 10-4	
	Ch 2 No. Valid Messages	N/A* ☐
	Ch 2 No. Err Messages	N/A* ☐
	Ch 2 Errored/Valid	N/A* ☐
	Ch 2 Errored/Valid < 10-4	N/A* ☐
9	END-TO-END SCHEME TESTS	
9.1	Signaling channel check	
9.1.1	Aided scheme 1 signaling channel test	
9.1.1.2	Local - remote end signal received	Yes* ☐ No* ☐ N/A* ☐

		***Delete as appropriate**
9.1.1.3	Remote - local end signal received	Yes* ☐ No* ☐ N/A* ☐
9.1.2	Aided scheme 2 signaling channel test	
	Local - remote end signal received	Yes* ☐ No* ☐ N/A* ☐
	Remote - local end signal received	Yes* ☐ No* ☐ N/A* ☐
10	MODEM InterMiCOM scheme testing	
	If applicable, provide details of scheme tests undertaken and results obtained.	
11	On-load checks	
	Test wiring removed?	Yes* ☐ No* ☐
11.1.1	Voltage inputs and phase rotation OK?	Yes* ☐ No* ☐
11.1.2	Current inputs and polarities OK?	Yes* ☐ No* ☐
11.2	On-load test performed?	Yes* ☐ No* ☐
	(If “**No**”, give reason why) …	
	Relay is correctly directionalized?	Yes* ☐ No* ☐ N/A* ☐
11.3	Signaling channel check	Yes* ☐ Tested in 9* ☐ N/A* ☐
12	Final checks	
	All test equipment, leads, shorts and test blocks removed safely?	Yes* ☐ No* ☐
	Disturbed customer wiring re-checked?	Yes* ☐ No* ☐ N/A* ☐
	All commissioning tests disabled?	Yes* ☐ No* ☐
	Application settings checked ?	Yes* ☐ No* ☐
	Circuit breaker operations counter reset?	Yes* ☐ No* ☐ N/A* ☐
	Current counters reset?	Yes* ☐ No* ☐ N/A* ☐
	Event records reset?	Yes* ☐ No* ☐
	Fault records reset?	Yes* ☐ No* ☐
	Disturbance records reset?	Yes* ☐ No* ☐
	Alarms reset?	Yes* ☐ No* ☐

	***Delete as appropriate**
LEDs reset?	Yes* ☐ No* ☐
Communications statistics reset?	Yes* ☐ No* ☐
Secondary front cover replaced?	Yes* ☐ No* ☐ N/A* ☐

COMMENTS #
(# Optional, for site observations or utility-specific notes).

Commissioning Engineer

Customer Witness

Date:

Date:

14 SETTING RECORD

Date: Engineer:
Station: Circuit:
System Frequency: Hz
VT Ratio: / V CT Ratio (tap in use): / A

14.1 Front Plate Information

Feeder protection relay	P44
Model number	
Serial number	
Rated current In	1A ☐ 5A ☐
Rated voltage Vn	
Auxiliary voltage Vx	

14.2 Setting Groups Used

	***Delete as appropriate**
Group 1	Yes* ☐ No* ☐
Group 2	Yes* ☐ No* ☐
Group 3	Yes* ☐ No* ☐
Group 4	Yes* ☐ No* ☐

14.3 0000 - System Data

0000	**SYSTEM DATA**	
0001	Language	English* ☐ Francais* ☐ Deutsche* ☐ Espanol* ☐
0002	Password	
0003	Sync. Fn. links	
0004	Description	
0005	Plant reference	
0006	Model number	
0008	Serial number	
0009	Frequency	
000B	Relay address	
0011	Software ref. 1	
00D1	Password control	Level 0* ☐ Level 1* ☐ Level 2* ☐
00D2	Password level 1	
00D3	Password level 2	

0700	CB CONTROL	P443 Model
0701	CB Control By	Disabled* ☐ Local* ☐ Remote* ☐ Local + Remote* ☐ Opto* ☐ Opto + Local* ☐ Opto + Remote* ☐ Opto + Rem. + Local ☐
0702	Close Pulse Time	
0703	Trip Pulse Time	
0705	Man Close Delay	
0706	CB Healthy Time	
0707	Check Sync. Time	
0709	Reset Lockout By	User Interface* ☐ CB Close* ☐
070A	Man Close RstDly.	
070B	Autoreclose Mode	No Operation* ☐ Auto* ☐ Non-Auto ☐
070C	Single Pole A/R	Disabled* ☐ Enabled* ☐
070D	Three Pole A/R	Disabled* ☐ Enabled* ☐
0711	CB Status Input	

0700	CB CONTROL	P446 Model
0701	CB Control By	Disabled* ☐ Local* ☐ Remote* ☐ Local + Remote* ☐ Opto* ☐ Opto + Local* ☐ Opto + Remote* ☐ Opto + Rem. + Local ☐
0702	Close Pulse Time	
0703	Trip Pulse Time	
0705	Man Close Delay	
0706	CB Healthy Time	
0707	Check Sync. Time	
0709	Rst CB Mon LO By	User Interface* ☐ CB Close* ☐
070A	CB Mon LO RstDly	
0711	CB1 Status Input	
077F	CB Status Time	
0780	CB2 Status Input	
0796	Res AROK By UI	Disabled* ☐ Enabled* ☐
0797	Res AROK By NoAR	Disabled* ☐ Enabled* ☐
0798	Res AROK By Ext	Disabled* ☐ Enabled* ☐
0799	Res AROK By TDly	Disabled* ☐ Enabled* ☐
079A	Res AROK By Tdly	
079B	Res LO By CB IS	Disabled* ☐ Enabled* ☐
079C	Res LO By UI	Disabled* ☐ Enabled* ☐
079D	Res LO By NoAR	Disabled* ☐ Enabled* ☐
079E	Res LO By ExtDDB	Disabled* ☐ Enabled* ☐
079F	Res LO By TDelay	Disabled* ☐ Enabled* ☐
07A0	LO Reset Time	

0800	DATE AND TIME	
0804	IRIG-B Sync.	Disabled* ☐ Enabled* ☐

0800	DATE AND TIME	
0805	IRIG-B Status	Card not fitted ☐ Card failed ☐ Signal healthy ☐ No signal ☐
0806	Battery Status	Dead ☐ Healthy ☐
0807	Battery Alarm	Disabled* ☐ Enabled* ☐
0813	SNTP Status	Disabled ☐ Trying Server 1 ☐ Trying Server 2 ☐ Server 1 OK ☐ Server 2 OK ☐ No response ☐ No valid clock ☐
	LocalTime Enable	Disabled ☐ Fixed ☐ Flexible ☐
0821	LocalTime Offset	
0822	DST Enable	Disabled* ☐ Enabled* ☐
0823	DST Offset	
0824	DST Start	First ☐ Second ☐ Third ☐ Fourth ☐ Last ☐
0825	DST Start Day	Monday ☐ Tuesday ☐ Wednesday ☐ Thursday ☐ Friday ☐ Saturday ☐
0826	DST Start Month	January ☐ February ☐ March ☐ April ☐ May ☐ June ☐ July ☐ August ☐ September ☐ October ☐ November ☐ December ☐
0827	DST Start Mins	
0828	DST End	First ☐ Second ☐ Third ☐ Fourth ☐ Last ☐
0829	DST End Day	Monday ☐ Tuesday ☐ Wednesday ☐ Thursday ☐ Friday ☐ Saturday ☐
082A	DST End Month	January ☐ February ☐ March ☐ April ☐ May ☐ June ☐ July ☐ August ☐ September ☐ October ☐ November ☐ December ☐
082B	DST End Mins	
0830	RP1 Time Zone	UTC ☐ Local ☐
0831	RP2 Time Zone	UTC ☐ Local ☐
0832	DNPOE Time Zone	UTC ☐ Local ☐
0833	Tunnel Time Zone	UTC ☐ Local ☐

0900	CONFIGURATION	
0902	Setting Group	Select via Menu* ☐ Select via Optos* ☐
0903	Active Settings	Group 1* ☐ Group 2* ☐ Group 3* ☐ Group 4* ☐
0907	Setting Group 1	Disabled* ☐ Enabled* ☐
0908	Setting Group 2	Disabled* ☐ Enabled* ☐
0909	Setting Group 3	Disabled* ☐ Enabled* ☐
090A	Setting Group 4	Disabled* ☐ Enabled* ☐
090B	Distance	Disabled* ☐ Enabled* ☐
090C	Directional E/F	Disabled* ☐ Enabled* ☐
0910	Overcurrent	Disabled* ☐ Enabled* ☐
0911	Neg Sequence O/C	Disabled* ☐ Enabled* ☐

0900	CONFIGURATION		
0912	Broken Conductor	Disabled* ☐	Enabled* ☐
0913	Earth Fault	Disabled* ☐	Enabled* ☐
0915	Sensitive E/F	Disabled* ☐	Enabled* ☐
0916	Residual O/V NVD	Disabled* ☐	Enabled* ☐
0917	Thermal Overload	Disabled* ☐	Enabled* ☐
0918	PowerSwing Block	Disabled* ☐	Enabled* ☐
091D	Volt Protection	Disabled* ☐	Enabled* ☐
091E	Freq Protection	Disabled* ☐	Enabled* ☐
091F	df/dt Protection	Disabled* ☐	Enabled* ☐
0920	CB Fail	Disabled* ☐	Enabled* ☐
0921	Supervision	Disabled* ☐	Enabled* ☐
0923	System Checks	Disabled* ☐	Enabled* ☐
0924	Auto-Reclose	Disabled* ☐	Enabled* ☐
0925	Input Labels	Invisible* ☐	Visible* ☐
0926	Output Labels	Invisible* ☐	Visible* ☐
0928	CT & VT Ratios	Invisible* ☐	Visible* ☐
0929	Record Control	Invisible* ☐	Visible* ☐
092A	Disturb Recorder	Invisible* ☐	Visible* ☐
092B	Measure't Setup	Invisible* ☐	Visible* ☐
092C	Comms Settings	Invisible* ☐	Visible* ☐
092D	Commission Tests	Invisible* ☐	Visible* ☐
092E	Setting Values	Primary* ☐	Secondary* ☐
092F	Control Inputs	Invisible* ☐	Visible* ☐
0935	Control I/P Config	Invisible* ☐	Visible* ☐
0936	Ctrl I/P Labels	Invisible* ☐	Visible* ☐
0939	Direct Access	Disabled* ☐ Hotkey only* ☐	CB Control Only* ☐ Enabled* ☐
0941	InterMiCOM^{64} Fiber	Disabled* ☐	Enabled* ☐
0950	Function Key	Invisible* ☐	Visible* ☐
09FF	LCD Contrast		

0A00	CT AND VT RATIOS	P443 Model
0A00	CT AND VT RATIOS	
0A01	Main VT Primary	
0A02	Main VT Secondary	
0A03	C/S VT Primary	
0A04	C/S VT Secondary	
0A07	Phase CT Primary	
0A08	Phase CT Secondary	
0A0B	SEF CT Primary	
0A0C	SEF CT Secondary	
0A0D	MComp CT Primary	
0A0E	MComp CT Secondary	

0A00	CT AND VT RATIOS	P443 Model
0A0F	C/S Input	A - N* ☐ B - N* ☐ C - N* ☐ A - B* ☐ B - C* ☐ C - A* ☐ A-N/1.732* ☐ B-N/1.732* ☐ C-N/1.732* ☐
0A10	Main VT Location	Line* ☐ Bus* ☐
0A11	CT Polarity	Standard* ☐ Inverted* ☐
0A13	SEF CT Polarity	Standard* ☐ Inverted* ☐
0A14	M CT Polarity	Standard* ☐ Inverted* ☐

0A00	CT AND VT RATIOS		Model Applicability
Note *The following settings relate to models which use Software Version A0-A and A0-B. These are different settings to those which applied to Software Release 57 and earlier.*			
0A01	Main VT Primary		P443 and P446
0A02	Main VT Sec'y		P443 and P446
0A03	C/S VT Primary		P443 only
0A03	CB1 C/S VT Primary		P446 only
0A04	C/S VT Sec'y		P443 only
0A04	CB1 C/S VT Sec'y		P446 only
0A05	CB2 C/S VT Primary		P446 only
0A06	CB2 C/S VT Sec'y		P446 only
0A07	Phase CT Primary		P443 and P446
0A08	Phase CT Sec'y		P443 and P446
0A09	Phase CT2 Primary		P446 only
0A0A	Phase CT2 Sec'y		P446 only
0A0B	SEF CT Primary		P443 and P446
0A0C	SEF CT Secondary		P443 and P446
0A0D	MComp CT Primary		P443 and P446
0A0E	MComp CT Sec'y		P443 and P446
0A0F	C/S Input	A - N* ☐ B - N* ☐ C - N* ☐ A - B* ☐ B - C* ☐ C - A* ☐ A-N/1.732* ☐ B-N/1.732* ☐ C-N/1.732* ☐	P443 only
0A0F	C/S Input	A - N* ☐ B - N* ☐ C - N* ☐ A - B* ☐ B - C* ☐ C - A* ☐	P446 only
0A10	Main VT Location	Line* ☐ Bus* ☐	P443 only
0A11	CT Polarity	Standard* ☐ Inverted* ☐	P443 and P446

0A00	CT AND VT RATIOS		Model Applicability
0A12	CT2 Polarity	Standard* ☐ Inverted* ☐	P443 only
0A13	SEF CT Polarity	Standard* ☐ Inverted* ☐	P443 and P446
0A14	M CT Polarity	Standard* ☐ Inverted* ☐	P443 and P446
0A21	CB1 CS VT PhShft	Degrees	P446 only
0A22	CB1 CS VT Mag.		P446 only
0A23	CB2 CS VT PhShft	Degrees	P446 only
0A24	CB2 CS VT Mag.		P446 only

0B00	RECORD CONTROL		
0B04	Alarm Event	Disabled* ☐	Enabled* ☐
0B05	Relay O/P Event	Disabled* ☐	Enabled* ☐
0B06	Opto Input Event	Disabled* ☐	Enabled* ☐
0B07	General Event	Disabled* ☐	Enabled* ☐
0B08	Fault rec. Event	Disabled* ☐	Enabled* ☐
0B09	Maint. rec. Event	Disabled* ☐	Enabled* ☐
0B0A	Protection Event	Disabled* ☐	Enabled* ☐

0C00	DISTURB. RECORDER			
0C01	Duration			
0C02	Trigger Position	Single* ☐	Extended* ☐	
0C04	Analog Channel 1			
0C05	Analog Channel 2			
0C06	Analog Channel 3			
0C07	Analog Channel 4			
0C08	Analog Channel 5			
0C09	Analog Channel 6			
0C0A	Analog Channel 7			
0C0B	Analog Channel 8			
0C0C	Digital Input 1			
0C0D	Input 1 Trigger	No Trigger* ☐	Trigger L - H* ☐	Trigger H - L* ☐
0C0E	Digital Input 2			
0C0F	Input 2 Trigger	No Trigger* ☐	Trigger L - H* ☐	Trigger H - L* ☐
0C10	Digital Input 3			
0C11	Input 3 Trigger	No Trigger* ☐	Trigger L - H* ☐	Trigger H - L* ☐
0C12	Digital Input 4			
0C13	Input 4 Trigger	No Trigger* ☐	Trigger L - H* ☐	Trigger H - L* ☐
0C14	Digital Input 5			
0C15	Input 5 Trigger	No Trigger* ☐	Trigger L - H* ☐	Trigger H - L* ☐
0C16	Digital Input 6			
0C17	Input 6 Trigger	No Trigger* ☐	Trigger L - H* ☐	Trigger H - L* ☐
0C18	Digital Input 7			
0C19	Input 7 Trigger	No Trigger* ☐	Trigger L - H* ☐	Trigger H - L* ☐

0C00	DISTURB. RECORDER	
0C1A	Digital Input 8	
0C1B	Input 8 Trigger	No Trigger* ☐ Trigger L - H* ☐ Trigger H - L* ☐
0C1C	Digital Input 9	
0C1D	Input 9 Trigger	No Trigger* ☐ Trigger L - H* ☐ Trigger H - L* ☐
0C1E	Digital Input 10	
0C1F	Input 10 Trigger	No Trigger* ☐ Trigger L - H* ☐ Trigger H - L* ☐
0C20	Digital Input 11	
0C21	Input 11 Trigger	No Trigger* ☐ Trigger L - H* ☐ Trigger H - L* ☐
0C22	Digital Input 12	
0C23	Input 12 Trigger	No Trigger* ☐ Trigger L - H* ☐ Trigger H - L* ☐
0C24	Digital Input 13	
0C25	Input 13 Trigger	No Trigger* ☐ Trigger L - H* ☐ Trigger H - L* ☐
0C26	Digital Input 14	
0C27	Input 14 Trigger	No Trigger* ☐ Trigger L - H* ☐ Trigger H - L* ☐
0C28	Digital Input 15	
0C29	Input 15 Trigger	No Trigger* ☐ Trigger L - H* ☐ Trigger H - L* ☐
0C2A	Digital Input 16	
0C2B	Input 16 Trigger	No Trigger* ☐ Trigger L - H* ☐ Trigger H - L* ☐
0C2C	Digital Input 17	
0C2D	Input 17 Trigger	No Trigger* ☐ Trigger L - H* ☐ Trigger H - L* ☐
0C2E	Digital Input 18	
0C2F	Input 18 Trigger	No Trigger* ☐ Trigger L - H* ☐ Trigger H - L* ☐
0C30	Digital Input 19	
0C31	Input 19 Trigger	No Trigger* ☐ Trigger L - H* ☐ Trigger H - L* ☐
0C32	Digital Input 20	
0C33	Input 20 Trigger	No Trigger* ☐ Trigger L - H* ☐ Trigger H - L* ☐
0C34	Digital Input 21	
0C35	Input 21 Trigger	No Trigger* ☐ Trigger L - H* ☐ Trigger H - L* ☐
0C36	Digital Input 22	
0C37	Input 22 Trigger	No Trigger* ☐ Trigger L - H* ☐ Trigger H - L* ☐
0C38	Digital Input 23	
0C39	Input 23 Trigger	No Trigger* ☐ Trigger L - H* ☐ Trigger H - L* ☐
0C3A	Digital Input 24	
0C3B	Input 24 Trigger	No Trigger* ☐ Trigger L - H* ☐ Trigger H - L* ☐
0C3C	Digital Input 25	
0C3D	Input 25 Trigger	No Trigger* ☐ Trigger L - H* ☐ Trigger H - L* ☐
0C3E	Digital Input 26	
0C3F	Input 26 Trigger	No Trigger* ☐ Trigger L - H* ☐ Trigger H - L* ☐
0C40	Digital Input 27	
0C41	Input 27 Trigger	No Trigger* ☐ Trigger L - H* ☐ Trigger H - L* ☐
0C42	Digital Input 28	
0C43	Input 28 Trigger	No Trigger* ☐ Trigger L - H* ☐ Trigger H - L* ☐
0C44	Digital Input 29	
0C45	Input 29 Trigger	No Trigger* ☐ Trigger L - H* ☐ Trigger H - L* ☐

0C00	DISTURB. RECORDER	
0C46	Digital Input 30	
0C47	Input 30 Trigger	No Trigger* ☐ Trigger L - H* ☐ Trigger H - L* ☐
0C48	Digital Input 31	
0C49	Input 31 Trigger	No Trigger* ☐ Trigger L - H* ☐ Trigger H - L* ☐
0C4A	Digital Input 32	
0C4B	Input 32 Trigger	No Trigger* ☐ Trigger L - H* ☐ Trigger H - L* ☐
	… continued …	
	Digital Input 128	
	Input 128 Trigger	No Trigger* ☐ Trigger L - H* ☐ Trigger H - L* ☐
0C50	Analog Channel 9	
0C51	Analog Channel 10	
0C52	Analog Channel 11	
0C53	Analog Channel 12	

0D00	MEASURE'T. SETUP	
0D01	Default Display	3Ph + N Current* ☐ 3h Voltage* ☐ Power* ☐ Date & Time* ☐ Description* ☐ Plant Reference* ☐ Frequency* ☐ Access Level* ☐
0D02	Local Values	Primary* ☐ Secondary* ☐
0D03	Remote Values	Primary* ☐ Secondary* ☐
0D04	Measurement Ref.	VA* ☐ VB* ☐ VC* ☐ IA* ☐ IB* ☐ IC* ☐
0D05	Measurement Mode	
0D06	Fix Dem. Period	
0D07	Roll Sub Period	
0D08	Num. Sub Periods	
0D09	Distance Unit	Kilometers* ☐ Miles* ☐
0D0A	Fault Location	Distance* ☐ Ohms* ☐ ______ % of Line*
0D0B	Remote2 Values	Primary* ☐ Secondary* ☐

0E00	COMMUNICATIONS	
0E01	RP1 Protocol	Courier* ☐ IEC870-5-103* ☐ DNP3.0* ☐
0E02	RP1 Address	
0E03	RP1 InactivTimer	
0E04	RP1 Baud Rate	1200* ☐ 2400* ☐ 4800* ☐ 9600* ☐ 19200* ☐ 38400* ☐
0E05	RP1 Parity	Odd* ☐ Even* ☐ None* ☐
0E06	RP1 Meas. Period	
0E07	RP1 Physical Link	EIA(RS)485* ☐ Fiber Optic* ☐
0E08	RP1 Time Sync.	Disabled* ☐ Enabled* ☐
0E0A	RP1 CS103 Blocking	Disabled* ☐ Monitor Blocking* ☐ Command Blocking* ☐ Not applicable* ☐
0E0C	RP1 Port Config.	K-Bus* ☐ EIA(RS)485* ☐ Not Applicable* ☐

0E00	COMMUNICATIONS	
0E0D	RP1 Comms Mode.	FT1.2 Frame* ☐ 10-bit Frame* ☐ Not Applicable* ☐
0E0F	Meas Scaling.	Primary* ☐ Secondary* ☐ Normalized* ☐ Not Applicable* ☐
0E10	Message Gap	
0E11	DNP Need Time	
0E12	DNP App Fragment	
0E13	DNP App Timeout	
0E14	DNP SBO Timeout	
0E15	DNP Link Timeout	
0E64	NIC Tunl Timeout	
0E6A	NIC Link Report	Alarm* ☐ Event* ☐ None* ☐
0E6B	NIC Link Timeout	
0E88	RP2 Port Config.	K Bus* ☐ EIA(RS)485* ☐
0E8A	RP2 Comms. Mode	IEC60870 FT1.2* ☐ 10-Bit Frame* ☐
0E90	RP2 Address	
0E92	RP2 InactivTimer	
0E94	RP2 Baud Rate	9600* ☐ 19200* ☐ 38400* ☐

0F00	COMMISSION TESTS	
0F05	Monitor Bit 1	
0F06	Monitor Bit 2	
0F07	Monitor Bit 3	
0F08	Monitor Bit 4	
0F09	Monitor Bit 5	
0F0A	Monitor Bit 6	
0F0B	Monitor Bit 7	
0F0C	Monitor Bit 8	

1000	CB MONITOR SETUP	P443 Model
1001	Broken I^	
1002	I^ Maintenance	Alarm Disabled* ☐ Alarm Enabled* ☐
1003	I^ Maintenance	
1004	I^ Lockout	Alarm Disabled* ☐ Alarm Enabled* ☐
1005	I^ Lockout	
1006	No. CB Ops. Maint.	Alarm Disabled* ☐ Alarm Enabled* ☐
1007	No. CB Ops. Maint.	
1008	No. CB Ops. Lock	Alarm Disabled* ☐ Alarm Enabled* ☐
1009	No. CB Ops. Lock	
100A	CB Time Maint.	Alarm Disabled* ☐ Alarm Enabled* ☐
100B	CB Time Maint.	
100C	CB Time Lockout	Alarm Disabled* ☐ Alarm Enabled* ☐
100D	CB Time Lockout	
100E	Fault Freq. Lock	Alarm Disabled* ☐ Alarm Enabled* ☐

1000	**CB MONITOR SETUP**	**P443 Model**			
100F	Fault Freq. Count				
1010	Fault Freq. Time				

1000	**CB MONITOR SETUP**	**P446 Model**			
1001	CB1 Broken I^				
1002	CB1 I^ Maintenance	Alarm Disabled*	☐	Alarm Enabled*	☐
1003	CB1 I^ Maintenance				
1004	CB1 I^ Lockout	Alarm Disabled*	☐	Alarm Enabled*	☐
1005	CB1 I^ Lockout				
1006	No. CB1 Ops. Maint.	Alarm Disabled*	☐	Alarm Enabled*	☐
1007	No. CB1 Ops. Maint.				
1008	No. CB1 Ops. Lock	Alarm Disabled*	☐	Alarm Enabled*	☐
1009	No. CB1 Ops. Lock				
100A	CB1 Time Maint.	Alarm Disabled*	☐	Alarm Enabled*	☐
100B	CB1 Time Maint.				
100C	CB1 Time Lockout	Alarm Disabled*	☐	Alarm Enabled*	☐
100D	CB1 Time Lockout				
100E	CB1 FlttFreqLock	Alarm Disabled*	☐	Alarm Enabled*	☐
100F	CB1 FltFreqCount				
1010	CB1 FltFreqTime				
1021	CB2 Broken I^				
1022	CB2 I^ Maintenance	Alarm Disabled*	☐	Alarm Enabled*	☐
1023	CB2 I^ Maintenance				
1024	CB2 I^ Lockout	Alarm Disabled*	☐	Alarm Enabled*	☐
1025	CB2 I^ Lockout				
1026	No. CB2 Ops. Maint.	Alarm Disabled*	☐	Alarm Enabled*	☐
1027	No. CB2 Ops. Maint.				
1028	No. CB2 Ops. Lock	Alarm Disabled*	☐	Alarm Enabled*	☐
1029	No. CB2 Ops. Lock				
102A	CB2 Time Maint.	Alarm Disabled*	☐	Alarm Enabled*	☐
102B	CB2 Time Maint.				
102C	CB2 Time Lockout	Alarm Disabled*	☐	Alarm Enabled*	☐
102D	CB2 Time Lockout				
102E	CB2 FlttFreqLock	Alarm Disabled*	☐	Alarm Enabled*	☐
102F	CB2 FltFreqCount				
1030	CB2 FltFreqTime				

1100	**OPTO CONFIG.**	
1101	Global Nominal V	
1102	Opto Input 1	
1103	Opto Input 2	
1104	Opto Input 3	
1105	Opto Input 4	
1106	Opto Input 5	

1100	OPTO CONFIG.	
1107	Opto Input 6	
1108	Opto Input 7	
1109	Opto Input 8	
110A	Opto Input 9	
110B	Opto Input 10	
110C	Opto Input 11	
110D	Opto Input 12	
110E	Opto Input 13	
110F	Opto Input 14	
1110	Opto Input 15	
1111	Opto Input 16	
1112	Opto Input 17	
1113	Opto Input 18	
1114	Opto Input 19	
1115	Opto Input 20	
1116	Opto Input 21	
1117	Opto Input 22	
1118	Opto Input 23	
1119	Opto Input 24	
111A	Opto Input 25	
111B	Opto Input 26	
111C	Opto Input 27	
111D	Opto Input 28	
111E	Opto Input 29	
111F	Opto Input 30	
1120	Opto Input 31	
1121	Opto Input 32	
1150	Filter Control	
1180	Characteristic	Standard 60% - 80%* ☐ 50% - 70%* ☐

1300	CTRL. I/P CONFIG.	
1301	Hotkey Enabled	
1310	Control Input 1	Latched* ☐ Pulsed* ☐
1311	Ctrl Command 1	
1314	Control Input 2	Latched* ☐ Pulsed* ☐
1315	Ctrl Command 2	
1318	Control Input 3	Latched* ☐ Pulsed* ☐
1319	Ctrl Command 3	
131C	Control Input 4	Latched* ☐ Pulsed* ☐
131D	Ctrl Command 4	
1320	Control Input 5	Latched* ☐ Pulsed* ☐
1321	Ctrl Command 5	
1324	Control Input 6	Latched* ☐ Pulsed* ☐
1325	Ctrl Command 6	

1300	CTRL. I/P CONFIG.	
1328	Control Input 7	Latched* ☐ Pulsed* ☐
1329	Ctrl Command 7	
132C	Control Input 8	Latched* ☐ Pulsed* ☐
132D	Ctrl Command 8	
1330	Control Input 9	Latched* ☐ Pulsed* ☐
1331	Ctrl Command 9	
1334	Control Input 10	Latched* ☐ Pulsed* ☐
1335	Ctrl Command 10	
1338	Control Input 11	Latched* ☐ Pulsed* ☐
1339	Ctrl Command 11	
133C	Control Input 12	Latched* ☐ Pulsed* ☐
133C	Ctrl Command 12	
1340	Control Input 13	Latched* ☐ Pulsed* ☐
1341	Ctrl Command 13	
1344	Control Input 14	Latched* ☐ Pulsed* ☐
1345	Ctrl Command 14	
1348	Control Input 15	Latched* ☐ Pulsed* ☐
1349	Ctrl Command 15	
134C	Control Input 16	Latched* ☐ Pulsed* ☐
134D	Ctrl Command 16	
1350	Control Input 17	Latched* ☐ Pulsed* ☐
1351	Ctrl Command 17	
1354	Control Input 18	Latched* ☐ Pulsed* ☐
1355	Ctrl Command 18	
1358	Control Input 19	Latched* ☐ Pulsed* ☐
1359	Ctrl Command 19	
135C	Control Input 20	Latched* ☐ Pulsed* ☐
135D	Ctrl Command 20	
1360	Control Input 21	Latched* ☐ Pulsed* ☐
1361	Ctrl Command 21	
1364	Control Input 22	Latched* ☐ Pulsed* ☐
1365	Ctrl Command 22	
1368	Control Input 23	Latched* ☐ Pulsed* ☐
1369	Ctrl Command 23	
136C	Control Input 24	Latched* ☐ Pulsed* ☐
136D	Ctrl Command 24	
1370	Control Input 25	Latched* ☐ Pulsed* ☐
1371	Ctrl Command 25	
1374	Control Input 26	Latched* ☐ Pulsed* ☐
1375	Ctrl Command 26	
1378	Control Input 27	Latched* ☐ Pulsed* ☐
1379	Ctrl Command 27	
137C	Control Input 28	Latched* ☐ Pulsed* ☐
137D	Ctrl Command 28	

1300	CTRL. I/P CONFIG.		
1380	Control Input 29	Latched* ☐	Pulsed* ☐
1381	Ctrl Command 29		
1384	Control Input 30	Latched* ☐	Pulsed* ☐
1385	Ctrl Command 30		
1388	Control Input 31	Latched* ☐	Pulsed* ☐
1389	Ctrl Command 31		
138C	Control Input 32	Latched* ☐	Pulsed* ☐
138D	Ctrl Command 32		

1700	FUNCTION KEYS		
1702	Fn. Key 1 Status	Unlock* ☐	Enable* ☐
1703	Fn. Key 1 Mode	Normal* ☐	Toggle* ☐
1704	Fn. Key 1 Label		
1705	Fn. Key 2 Status	Unlock* ☐	Enable* ☐
1706	Fn. Key 2 Mode	Normal* ☐	Toggle* ☐
1707	Fn. Key 2 Label		
1708	Fn. Key 3 Status	Unlock* ☐	Enable* ☐
1709	Fn. Key 3 Mode	Normal* ☐	Toggle* ☐
170A	Fn. Key 3 Label		
170B	Fn. Key 4 Status	Unlock* ☐	Enable* ☐
170C	Fn. Key 4 Mode	Normal* ☐	Toggle* ☐
170D	Fn. Key 4 Label		
170E	Fn. Key 5 Status	Unlock* ☐	Enable* ☐
170F	Fn. Key 5 Mode	Normal* ☐	Toggle* ☐
1710	Fn. Key 5 Label		
1711	Fn. Key 6 Status	Unlock* ☐	Enable* ☐
1712	Fn. Key 6 Mode	Normal* ☐	Toggle* ☐
1713	Fn. Key 6 Label		
1714	Fn. Key 7 Status	Unlock* ☐	Enable* ☐
1715	Fn. Key 7 Mode	Normal* ☐	Toggle* ☐
1716	Fn. Key 7 Label		
1717	Fn. Key 8 Status	Unlock* ☐	Enable* ☐
1718	Fn. Key 8 Mode	Normal* ☐	Toggle* ☐
1719	Fn. Key 8 Label		
171A	Fn. Key 9 Status	Unlock* ☐	Enable* ☐
171B	Fn. Key 9 Mode	Normal* ☐	Toggle* ☐
171C	Fn. Key 9 Label		
171D	Fn. Key 10 Status	Unlock* ☐	Enable* ☐
171E	Fn. Key 10 Mode	Normal* ☐	Toggle* ☐
171F	Fn. Key 10 Label		

1900	IED CONFIGURATOR		
1905	Switch Conf. Bank	No Action* ☐	Switch Banks* ☐
1970	GoEna	Disabled* ☐	Enabled* ☐

1900	IED CONFIGURATOR			
1971	Test Mode	Disabled* ☐ Forced* ☐	Pass Through* ☐	
1972	VOP Test Pattern			
1973	Ignore Test Flag	No* ☐	Yes* ☐	

1500	INTERMiCOM COMMS			
1510	Source Address			
1511	Received Address			
1512	Baud Rate	600* ☐ 4800* ☐	1200* ☐ 9600* ☐	2400* ☐ 19200* ☐
1520	Ch Statistics	Invisible* ☐	Visible* ☐	
1540	Ch Diagnostics	Invisible* ☐	Visible* ☐	

1600	INTERMiCOM CONF.	
1601	IM Msg Alarm Lvl	
1610	IM1 Cmd Type	
1611	IM1 FallBackMode	
1612	IM1 DefaultValue	
1613	IM1 FrameSyncTim	
1618	IM2 Cmd Type	
1619	IM2 FallBackMode	
161A	IM2 DefaultValue	
161B	IM2 FrameSyncTim	
1620	IM3 Cmd Type	
1621	IM3 FallBackMode	
1622	IM3 DefaultValue	
1623	IM3 FrameSyncTim	
1628	IM4 Cmd Type	
1629	IM4 FallBackMode	
162A	IM4 DefaultValue	
162B	IM4 FrameSyncTim	
1630	IM5 Cmd Type	
1631	IM5 FallBackMode	
1632	IM5 DefaultValue	
1633	IM5 FrameSyncTim	
1638	IM6 Cmd Type	
1639	IM6 FallBackMode	
163A	IM6 DefaultValue	
163B	IM6 FrameSyncTim	
1640	IM7 Cmd Type	
1641	IM7 FallBackMode	
1642	IM7 DefaultValue	
1643	IM7 FrameSyncTim	
1648	IM8 Cmd Type	

1600	**INTERMiCOM CONF.**	
1649	IM8 FallBackMode	
164A	IM8 DefaultValue	
164B	IM8 FrameSyncTim	

2000	**PROT COMMS/IM64**			
2001	Scheme Setup	2 end ☐	dual red. ☐	3 end ☐
2002/3	Address			
2010	Comms Mode			
2011	Baud Rate Ch1	56kbits ☐	64kbits ☐	
2012	Baud Rate Ch2	56kbits ☐	64kbits ☐	
2013	Clock Source Ch1	Internal ☐	External ☐	
2014	Clock Source Ch2	Internal ☐	External ☐	
2015	Ch1 N*64kbits/s			
2016	Ch2 N*64kbits/s			
2018	Comm Fail Timer			
2019	Comm Fail Mode			
201E	Channel Timeout			
201F	IM Msg Alarm Lvl			
2030	IM1 Cmd Type			
2031	IM1 FallBackMode			
2032	IM1 DefaultValue			
2034	IM2 Cmd Type			
2035	IM2 FallBackMode			
2036	IM2 DefaultValue			
2038	IM3 Cmd Type			
2039	IM3 FallBackMode			
203A	IM3 DefaultValue			
203C	IM4 Cmd Type			
203D	IM4 FallBackMode			
203E	IM4 DefaultValue			
2040	IM5 Cmd Type			
2041	IM5 FallBackMode			
2042	IM5 DefaultValue			
2044	IM6 Cmd Type			
2045	IM6 FallBackMode			
2046	IM6 DefaultValue			
2048	IM7 Cmd Type			
2049	IM7 FallBackMode			
204A	IM7 DefaultValue			
204C	IM8 Cmd Type			
204D	IM8 FallBackMode			
204E	IM8 DefaultValue			

2900	CNTRL. I/P LABELS	
2901	Control Input 1	
2902	Control Input 2	
2903	Control Input 3	
2904	Control Input 4	
2905	Control Input 5	
2906	Control Input 6	
2907	Control Input 7	
2908	Control Input 8	
2909	Control Input 9	
290A	Control Input 10	
290B	Control Input11	
290C	Control Input 12	
290D	Control Input 13	
290E	Control Input 14	
290F	Control Input 15	
2910	Control Input 16	
2911	Control Input 17	
2912	Control Input 18	
2913	Control Input 19	
2914	Control Input 20	
2915	Control Input 21	
2916	Control Input 22	
2917	Control Input 23	
2918	Control Input 24	
2919	Control Input 25	
291A	Control Input 26	
291B	Control Input 27	
291C	Control Input 28	
291D	Control Input 29	
291E	Control Input 30	
291F	Control Input 31	
2920	Control Input 32	

3000	LINE PARAMETERS				
Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3001/2	Line Length (km/miles*)				
3003	Line Impedance				
3004	Line Angle				
3005	kN Residual Comp				
3006	kN Residual Angle				
3007	Mutual Comp				
3008	kZm Mutual Set				
3009	kZm Mutual Angle				

3000	**LINE PARAMETERS**				
Group 1 Settings		**Group 1 Settings**	**Group 2 Settings**	**Group 3 Settings**	**Group 4 Settings**
300A	Mutual cut-off (k)				
300B	Phase Sequence				
300C	Trip Mode				
3010	Line Charging Y				

3100	**DISTANCE SETUP**				
Group 1 Settings		**Group 1 Settings**	**Group 2 Settings**	**Group 3 Settings**	**Group 4 Settings**
310C	Setting Mode				
3111	Phase Chars				
3112	Quad Resistance				
3113	Fault Resistance				
3120	Zone 1 Ph Status				
3121	Zone 1 Ph Reach				
3130	Zone 2 Ph Status				
3131	Zone 2 Ph Reach				
3140	Zone 3 Ph Status				
3141	Zone 3 Ph Reach				
3142	Zone 3 Ph Offset				
3143	Z3Ph Rev Reach				
3150	Zone P Ph Status				
3151	Zone P Ph Dir				
3152	Zone P Ph Reach				
3160	Zone 4 Ph Status				
3161	Zone 4 Ph Reach				
3171	Ground Chars				
3172	Quad Resistance				
3173	Fault Resistance				
3180	Zone1 Gnd Status				
3181	Zone1 Gnd Reach				
3190	Zone2 Gnd Status				
3191	Zone2 Gnd Reach				
31A0	Zone3 Gnd Status				
31A1	Zone3 Gnd Reach				
31A2	Zone3 Gnd Offset				
31A3	Z3Gnd Rev Reach				
31B0	ZoneP Gnd Status				
31B1	ZoneP Gnd Direction				
31B2	ZoneP Gnd Reach				
31C0	Zone4 Gnd Status				
31C1	Zone4 Gnd Reach				
31D0	Digital Filter				
31D1	CVT Filters				

3100	DISTANCE SETUP				
Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
31D2	SIR Setting				
31D3	Load Blinders				
31D4	Load/B Impedance				
31D5	Load/B Angle				
31D6	Load Blinder V<				
31D7	Distance Polarizing				
31E0	DELTA DIRECTIONAL				
31E1	Dir. Status				
31E2	AidedDeltaStatus				
31E3	Dir. Char Angle				
31E4	Dir. V Fwd				
31E5	Dir. V Rev				
31E6	Dir. I Fwd				
31E7	Dir. I Rev				

3200	DIST. ELEMENTS				
Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3202	Z1 Phase Reach				
3203	Z1 Phase Angle				
3207	Z1 Ph Resistive				
3208	Z1 Tilt Top-Line				
3209	Z1 Ph Sensit. Iph>1				
3210	Z2 Ph. Reach				
3211	Z2 Ph. Angle				
3215	Z2 Ph Resistance				
3216	Z2 Tilt Top-Line				
3217	Z2 Ph Sensit. Iph>2				
3220	Z3 Ph. Reach				
3221	Z3 Ph. Angle				
3222	Z3’ Ph Rev Reach				
3225	Z3’ Ph Rev Reach				
3226	Z3 Ph Res. Rev				
3227	Z3 Tilt Top-Line				
3228	Z3 Ph Sensit. Iph>3				
3230	ZP Ph Reach				
3231	ZP Ph Angle				
3235	ZP Ph Resistance				
3236	ZP Tilt Top-Line				
3237	ZP Ph Sensit. Iph>P				
3240	Z4 Ph. Reach				
3241	Z4 Ph. Angle				
3242	Z4 Ph Resistive				

3200	DIST. ELEMENTS				
Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3245	Z4 Tilt Top-Line				
3246	Z4 Ph Sensit. Iph>4				
3251	Z1 Gnd. Reach				
3252	Z1 Gnd Angle				
3253	Z1 Dynamic Tilt				
3254	Z1 Tilt Top Line				
3255	kZN1 Res. Comp.				
3256	kZN1 Res. Angle				
3257	kZm1 Mut. Comp.				
3258	kZm1 Mut. Angle				
3259	R1 Gnd. Resistive				
325B	Z1 Sensit Ignd>1				
3260	Z2 Gnd. Reach				
3261	Z2 Gnd. Angle				
3263	Z2 Dynamic Tilt				
3264	Z2 Tilt Top Line				
3265	kZN1 Res. Comp.				
3266	kZN2 Res. Angle				
3267	kZm2 Mut. Comp				
3268	kZm2 Mut. Angle				
3269	R2 Gnd Resistive				
326B	Z2 Sensit Ignd>2				
3270	Z3 Gnd Reach				
3271	Z3 Gnd Angle				
3272	Z3’ Gnd Rev Rch				
3273	Z3 Dynamic Tilt				
3274	Z3 Tilt Top Line				
3275	kZN3 Res. Comp.				
3276	kZN3 Res. Angle				
3277	kZN3 Mut. Comp.				
3278	kZN3 Mut. Angle				
3279	R3 Gnd. Res. Fwd				
327A	R3 Gnd. Res. Rev				
327C	Z3 Sensit Ignd>3				
3280	ZP Ground Reach				
3281	ZP Ground Angle				
3283	ZP Dynamic Tilt				
3284	ZP Tilt Top Line				
3285	kZNP Res. Comp				
3286	kZNP Res. Angle				
3287	kZmP Mut. Comp				
3288	kZmP Mut. Angle				
3289	RP Gnd Resistive				

3200	DIST. ELEMENTS				
Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
328B	ZP Sensit. Ignd>P				
3290	Z4 Gnd. Reach				
3291	Z4 Gnd Angle				
3293	Z4 Dynamic Tilt				
3294	Z4 Tilt Top Line				
3295	kZN4 Res. Comp				
3296	kZN4 Res. Angle				
3297	kZm4 Mut Comp.				
3298	kZm4 Mut Angle				
3299	R4 G Resistive				
329B	Z4 Gnd Sensitivity				

3400	SCHEME LOGIC				
Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3408	Zone 1 Tripping				
3409	Zone 1 Ph Delay				
340A	Zone 1 Gnd Delay				
3410	Zone 2 Tripping				
341	Zone 2 Ph Delay				
3412	Zone 2 Gnd Delay				
3418	Zone 3 Tripping				
3419	Zone 3 Ph Delay				
341A	Zone 3 Gnd Delay				
3420	Zone P Tripping				
3421	Zone P Ph Delay				
3422	Zone P Gnd Delay				
3428	Zone 4 Tripping				
3429	Zone 4 Ph Delay				
342A	Zone 4 Gnd Delay				
3441	Aided 1 Selection				
3442	Aided 1 Distance				
3443	Aided 1 Dist Dly				
3444	Aided 1 DEF				
3445	Aided 1 DEF Dly				
3446	Aided 1 DEF Trip				
3447	Aided 1 Delta				
3448	Aided1 Delta Dly				
3449	Aided1 DeltaTrip				
344A	tRev. Guard				
344B	Unblocking Delay				
3450	Weak Infeed				
3451	WI Single Pole Trip				

3400	SCHEME LOGIC				
Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3452	WI V< Threshold				
3453	WI Trip Delay				
3458	Custom Send Mask				
3459	Custom Time PU				
345A	Custom Time DO				
3461	Aided 2 Selection				
3462	Aided 2 Distance				
3463	Aided 2 Dist Dly				
3464	Aided 2 DEF				
3465	Aided 2 DEF Dly				
3466	Aided 2 DEF Trip				
3467	Aided 2 Delta				
3468	Aided2 Delta Dly				
3469	Aided2 DeltaTrip				
346A	tRev. Guard				
346B	Unblocking Delay				
3470	Weak Infeed				
3471	WI Single Pole Trip				
3472	WI V< Threshold				
3473	WI Trip Delay				
3478	Custom Send Mask				
3479	Custom Time PU				
347A	Custom Time DO				
3480	Trip on Close				
3481	SOTF Status				
3482	SOTF Delay				
3483	SOTF Tripping				
3484	TOR Status				
3485	TOR Tripping				
3486	TOC Reset Delay				
3487	SOTF Pulse				
3488	TOC Delay				
34B1	Zone 1Ext Scheme				
34B2	Zone1 Ext Ph				
34B3	Zone1 Ext Gnd				
34C1	LoL Scheme				
34C3	Lol I<				
34C4	LoL Window				

3500	OVERCURRENT				
Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3501	I>1 Status				

3500	OVERCURRENT				
Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3502	I>1 Function				
3503	I>1 Directional				
3504	I>1 Current Set				
3505	I>1 Time Delay				
3506	I>1 TMS				
3507	I>1 Time Dial				
3508	I>1 Reset Char				
3509	I>1 tRESET				
350A	I>2 Status				
350B	I>2 Function				
350C	I>2 Directional				
350D	I>2 Current Set				
350E	I>2 Time Delay				
350F	I>2 TMS				
3510	I>2 Time Dial				
3511	I>2 Reset Char				
3512	I>2 tRESET				
3513	I>3 Status				
3514	I>3 Directional				
3515	I>3 Current Set				
3516	I>3 Time Delay				
3518	I>4 Status				
3519	I>4 Directional				
351A	I>4 Current Set				
351B	I>4 Time Delay				
351C	I> Char Angle				
351D	I> Blocking				

3600	NEG. SEQ. O/C				
Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3601	I2> Status				
3602	I2> Directional				
3603	I2> VTS				
3604	I2> Current Set				
3605	I2> Time Delay				
3606	I2> Char Angle				
3607	I2> V2pol Set				

3700	BROKEN CONDUCTOR				
Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3701	Broken Conductor				

3700	BROKEN CONDUCTOR				
Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3702	I2/I1 Setting				
3703	I2/I1 Time Delay				

3800	EARTH FAULT				
Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3801	IN>1 Status				
3825	IN>1 Function				
3826	IN>1 Directional				
3829	IN>1 Current Set				
382A	IN1>1 IDG Is				
382C	IN>1 Time Delay				
382D	IN>1 TMS				
382E	IN>1 Time Dial				
3830	IN1>1 IDG Time				
3832	IN>1 Reset Char				
3833	IN>1 tRESET				
3835	IN>2 Status				
3836	IN>2 Function				
3837	IN>2 Directional				
383A	IN>2 Current Set				
383B	IN2>1 IDG Is				
383D	IN>2 Time Delay				
383E	IN>2 TMS				
383F	IN>2 Time Dial				
3841	IN2>1 IDG Time				
3843	IN>2 Reset Char				
3844	IN>2 tRESET				
3846	IN>3 Status				
3847	IN>3 Directional				
384A	IN>3 Current Set				
384B	IN>3 Time Delay				
384D	IN>4 Status				
384E	IN>4 Directional				
3851	IN>4 Current Set				
3852	IN>4 Time Delay				
3854	IN> Blocking				
3856	IN> Char Angle				
3857	IN> Polarization				
3859	IN> VNpol Set				
385A	IN> V2pol Set				
385B	IN> I2pol Set				

3900	AIDED DEF				
Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3902	DEF Status				
3903	DEF Polarizing				
3904	DEF Char Angle				
3905	DEF VNpol Set				
3906	DEF V2pol Set				
3907	DEF FWD Set				
3908	DEF REV Set				

3A00	SENSITIVE E/F				
Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3A01	Sens E/F Options				
3A02	ISEF>1 Function				
3A2B	ISEF>1 Direction				
3A2E	ISEF>1 Current				
3A2F	ISEF>1 IDG Is				
3A31	ISEF>1 Delay				
3A32	ISEF>1 TMS				
3A33	ISEF>1 Time Dial				
3A36	ISEF>1 Reset Chr				
3A37	ISEF>1 tRESET				
3A3A	ISEF>2 Function				
3A3B	ISEF>2 Direction				
3A3E	ISEF>2 Current				
3A3F	ISEF>2 IDG Is				
3A41	ISEF>2 Delay				
3A42	ISEF>2 TMS				
3A43	ISEF>2 Time Dial				
3A46	ISEF>2 Reset Chr				
3A47	ISEF>2 tRESET				
3A49	ISEF>3 Status				
3A4A	ISEF>3 Direction				
3A4D	ISEF>3 Current				
3A4E	ISEF>3 Delay				
3A50	ISEF>4 Status				
3A51	ISEF>4 Direction				
3A54	ISEF>4 Current				
3A55	ISEF>4 Delay				
3A57	ISEF> Blocking				
3A57	ISEF DIRECTIONAL				
3A59	ISEF> Char Angle				
3A5A	ISEF> Vpol Input				
3A5B	ISEF> VNpol Set				

3A00	SENSITIVE E/F				
Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3A5D	Wattmetric SEF				
3A5E	PN> Setting				

3B00	RESIDUAL O/V NVD				
Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3B01	VN Input				
3B02	VN>1 Function				
3B03	VN>1 Voltage Set				
3B04	VN>1 Time Delay				
3B05	VN>1 TMS				
3B06	VN>1 tReset				
3B07	VN>2 Status				
3B08	VN>2 Voltage Set				
3B09	VN>2 Time Delay				

3C00	THERMAL OVERLOAD				
Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3C01	Characteristic				
3C02	Thermal Trip				
3C03	Thermal Alarm				
3C04	Time Constant 1				
3C05	Time Constant 2				

3D00	POWER SWING BLK				
Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3D01	PSB Status				
3D03	Zone 1 Ph PSB				
3D05	Zone 2 Ph PSB				
3D07	Zone 3 Ph PSB				
3D09	Zone P Ph PSB				
3D0B	Zone 4 Ph PSB				
3D0D	Zone 1 Gnd PSB				
3D1F	Zone 2 Gnd PSB				
3D11	Zone 3 Gnd PSB				
3D13	Zone P Gnd PSB				
3D15	Zone 4 Gnd PSB				
3D20	PSB Unblocking				
3D21	PSB Unblock Dly				
3D22	PSB Reset Delay				
3D23	OST Mode				

3D00	POWER SWING BLK				
Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
3D24	Z5				
3D25	Z6				
3D26	Z5’				
3D27	Z6’				
3D28	R5				
3D29	R6				
3D2A	R5’				
3D2B	R6’				
3D2C	Blinder Angle				
3D2D	Delta T				
3D2E	Tost				

4200	VOLTAGE PROTECTION				
Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
4202	V< Measur’t. Mode				
4203	V< Operate Mode				
4204	V<1 Function				
4205	V<1 Voltage Set				
4206	V<1 Time Delay				
4207	V<1 TMS				
4208	V<1 Poledead Inh				
4209	V<2 Status				
420A	V<2 Voltage Set				
420B	V<2 Time Delay				
420C	V<2 Poledead Inh				
420E	V> Measur’t. Mode				
420F	V> Operate Mode				
4210	V>1 Function				
4211	V>1 Voltage Set				
4212	V>1 Time Delay				
4213	V>1 TMS				
4214	V>2 Status				
4215	V>2 Voltage Set				
4216	V>2 Time Delay				
4223	V1>1 Cmp Funct				
4224	V1>1 Cmp Vlt Set				
4225	V1>1 Cmp Tim Dly				
4226	V1>1 CmpTMS				
4227	V1>2 Cmp Status				
4228	V1>2 Vlt Set				
4229	V1>2 CmpTim Dly				

4300	**FREQUENCY PROTECTION**				
Group 1 Settings		**Group 1 Settings**	**Group 2 Settings**	**Group 3 Settings**	**Group 4 Settings**
4301	UNDER FREQUENCY				
4302	F<1 Status				
4303	F<1 Setting				
4304	F<1 Time Delay				
4305	F<2 Status				
4306	F<2 Setting				
4307	F<2 Time Delay				
4308	F<3 Status				
4309	F<3 Setting				
430A	F<3 Time Delay				
430B	F<4 Status				
430C	F<4 Setting				
430D	F<4 Time Delay				
430E	F< Function Link				
430F	OVER FREQUENCY				
4310	F>1 Status				
4311	F>1 Setting				
4312	F>1 Time Delay				
4313	F>2 Status				
4314	F>2 Setting				
4315	F>2 Time Delay				

4400	**DF/DT PROTECTION**				
Group 1 Settings		**Group 1 Settings**	**Group 2 Settings**	**Group 3 Settings**	**Group 4 Settings**
4401	df/dt Avg.Cycles				
4404	df/dt>1 Status				
4405	df/dt>1 Setting				
4406	df/dt>1 Dir'n				
4407	df/dt>1 Time				
440B	df/dt>2 Status				
440C	df/dt>2 Setting				
440D	df/dt>2 Dir'n				
440E	df/dt>2 Time				
4412	df/dt>3 Status				
4413	df/dt>3 Setting				
4414	df/dt>3 Dir'n				
4415	df/dt>3 Time				
4419	df/dt>4 Status				
441A	df/dt>4 Setting				
441B	df/dt>4 Dir'n				
441C	df/dt>4 Time				

4500	CB FAIL & P. DEAD				
Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
4502	CB Fail 1 Status				
4503	CB Fail 1 Timer				
4504	CB Fail 2 Status				
4505	CB Fail 2 Timer				
4506	Volt Prot. Reset				
4507	Ext. Prot. Reset				
4508	WI Prot. Reset				
450B	I< Current Set				
450D	ISEF< Current				
450E	BLOCKED O/C				
450F	Remove I> Start				
4510	Remove IN> Start				

4600	SUPERVISION				
Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
4601	VTS Mode				
4602	VTS Status				
4603	VTS Reset Mode				
4604	VTS Time Delay				
4605	VTS I> Inhibit				
4606	VTS I2> Inhibit				
4607	CT SUPERVISION				
4608	CTS Status				
4609	CTS VN< Inhibit				
460A	CTS IN> Set				
460B	CTS Time Delay				
460E	INRUSH DETECTION				
460F	I>2nd Harmonic				
4610	WEAK INFEED BLK				
4611	WI Inhibit				
4612	I0/I2 Setting				

4800	SYSTEM CHECKS	P443 Model			
Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
4815	Live Voltage				
4816	Dead Voltage				
4818	CS1 Status				
4819	CS1 Phase Angle				
481A	CS1 Slip Control				
481B	CS1 Slip Freq.				
481C	CS1 Slip Timer				

4800	SYSTEM CHECKS	P443 Model			
Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
481D	CS2 Status				
481E	CS2 Phase Angle				
481F	CS2 Slip Control				
4820	CS2 Slip Freq.				
4821	CS2 Slip Timer				
4822	CS Undervoltage				
4823	CS Overvoltage				
4824	CS Diff. Voltage				
4825	CS Voltage Block				
4827	SS Status				
4828	SS Phase Angle				
4829	SS Under V Block				
482A	SS Undervoltage				
482B	SS Timer				

4800	SYSTEM CHECKS	P446 Model			
Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
VOLTAGE MONITORS					
4885	Live Line				
4886	Dead Line				
4887	Live Bus 1				
4888	Dead Bus 1				
4889	Live Bus 2				
488A	Dead Bus 2				
488B	CS UV				
488C	CS OV				
488D	Sys Checks CB1				
488E	CB1 CS Volt. Blk				
488F	CB1 CS1 Status				
4890	CB1 CS1 Angle				
4891	CB1 CS1 VDiff				
4892	CB1 CS1 SlipCtrl				
4893	CB1 CS1 SlipFreq				
4894	CB1 CS2 Status				
4895	CB1 CS2 Angle				
4896	CB1 CS2 VDiff				
4897	CB1 CS2 SlipCtrl				
4898	CB1 CS2 SlipFreq				
4899	CB1 CS Adaptive				
489A	CB1 Cl Time				
489B	Sys Checks CB2				
489C	CB2 CS Volt. Blk				

4800	SYSTEM CHECKS	P446 Model			
Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
489D	CB2 CS1 Status				
489E	CB2 CS1 Angle				
489F	CB2 CS1 VDiff				
48A0	CB2 CS1 SlipCtrl				
48A1	CB2 CS1 SlipFreq				
48A2	CB2 CS2 Status				
48A3	CB2 CS2 Angle				
48A4	CB2 CS2 VDiff				
48A5	CB2 CS2 SlipCtrl				
48A6	CB2 CS2 SlipFreq				
48A7	CB2 CS Adaptive				
48A8	CB2 Cl Time				
48B1	Num CBs				
48B2	CB1M SC Required				
48B3	CB1M SC CS1				
48B4	CB1M SC CS2				
48B5	CB1M SC DLLB				
48B6	CB1M SC LLDB				
48B7	CB1M SC DLDB				
48B8	CB2M SC Required				
48B9	CB2M SC CS1				
48BA	CB2M SC CS2				
48BB	CB2M SC DLLB				
48BC	CB2M SC LLDB				
48BD	CB2M SC DLDB				

4900	AUTO-RECLOSE	P443 Model			
Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
4905	Single Pole Shot				
4906	Three Pole Shot				
4907	1 Pole Dead Time				
4908	Dead Time 1				
4909	Dead Time 2				
490A	Dead Time 3				
490B	Dead Time 4				
490C	CB Healthy Time				
490F	Reclaim Time				
4910	AR Inhibit Time				
4925	Check Sync Time				
4927	Z2T AR				
4928	Z3T AR				
4929	ZPT AR				

4900	AUTO-RECLOSE	P443 Model			
Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
492A	Z4T AR				
492B	DEF Aided AR				
492C	Dir. Comp AR				
492D	TOR AR				
492F	I>1 AR				
4930	I>2 AR				
4931	I>3 AR				
4932	I>4 AR				
4933	IN>1 AR				
4934	IN>2 AR				
4935	IN>3 AR				
4936	IN>4 AR				
4939	Mult Phase AR				
493A	Dead Time Start				
493B	Discrim Time				
493C	ISEF>1 AR				
493D	ISEF>2 AR				
493E	ISEF>3 AR				
493F	ISEF>4 AR				
4940	SYSTEM CHECKS				
4941	CS1 Close Enable				
4942	CS2 Close Enable				
4943	LiveLine/DeadBus				
4944	DeadLine/LiveBus				
4945	DeadLine/DeadBus				
4946	CS AR Immediate				
4947	SysChk on Shot 1				

4900	AUTO-RECLOSE	P446 Model			
Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
4950	Num CBs				
4951	AR Mode				
4953	Lead/Foll AR Mode				
4955	Leader Select By				
4956	Select Leader				
4957	BF if LFail Cls				
4958	Dynamic F/L				
4959	AR Shots				
495C	Multi Phase AR				
495D	Discrim Time				
4960	CB IS Time				
4961	CB IS MemoryTime				

4900	AUTO-RECLOSE	P446 Model			
Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
4962	DT Start by Prot				
4963	3PDTStart WhenLD				
4964	DTStart By CB Op				
4966	Dead Line Time				
4967	SP AR Dead Time				
4968	3P AR DT Shot 1				
4969	3P AR DT Shot 2				
496A	3P AR DT Shot 3				
496B	3P AR DT Shot 4				
496C	Follower Time				
496D	SPAR ReclaimTime				
496E	3PAR ReclaimTime				
496F	AR CBHealthy Time				
4970	AR CheckSync Time				
4972	Z1 AR				
4974	Dist Aided AR				
4975	Z2T AR				
4976	Z3T AR				
4977	ZPT AR				
4978	Z4T AR				
4979	DEF Aided AR				
497A	Dir. Aided AR				
497B	TOR AR				
497C	I>1 AR				
497D	I>2 AR				
497E	I>3 AR				
497F	I>4 AR				
4980	IN>1 AR				
4981	IN>2 AR				
4982	IN>3 AR				
4983	IN>4 AR				
4984	ISEF>1 AR				
4985	ISEF>2 AR				
4986	ISEF>3 AR				
4987	ISEF>4 AR				
	AR SYS CHECKS				
49A6	CB1L SC All				
49A7	CB1L SC Shot 1				
49A8	CB1L SC ClsNoDly				
49A9	CB1L SC CS1				
49AA	CB1L SC CS2				
49AB	CB1L SC DLLB				
49AC	CB1L SC LLDB				

4900	AUTO-RECLOSE	P446 Model			
Group 1 Settings		**Group 1 Settings**	**Group 2 Settings**	**Group 3 Settings**	**Group 4 Settings**
49AD	CB1L SC DLDB				
49AE	CB2L SC All				
49AF	CB2L SC Shot 1				
49B0	CB2L SC ClsNoDly				
49B1	CB2L SC CS1				
49B2	CB2L SC CS2				
49B3	CB2L SC DLLB				
49B4	CB2L SC LLDB				
49B5	CB2L SC DLDB				
49B6	CB1F SC All				
49B7	CB1F SC Shot 1				
49B8	CB1F SC CS1				
49B9	CB1F SC CS2				
49BA	CB1F SC DLLB				
49BB	CB1F SC LLDB				
49BC	CB1F SC DLDB				
49BD	CB2F SC All				
49BE	CB2F SC Shot 1				
49BF	CB2F SC CS1				
49C0	CB2F SC CS2				
49C1	CB2F SC DLLB				
49C2	CB2F SC LLDB				
49C3	CB2F SC DLDB				

4A00	INPUT LABELS				
Group 1 Settings		**Group 1 Settings**	**Group 2 Settings**	**Group 3 Settings**	**Group 4 Settings**
4A01	Opto Input 1				
4A02	Opto Input 2				
4A03	Opto Input 3				
4A04	Opto Input 4				
4A05	Opto Input 5				
4A06	Opto Input 6				
4A07	Opto Input 7				
4A08	Opto Input 8				
4A09	Opto Input 9				
4A0A	Opto Input 10				
4A0B	Opto Input 11				
4A0C	Opto Input 12				
4A0D	Opto Input 13				
4A0E	Opto Input 14				
4AOF	Opto Input 15				
4A10	Opto Input 16				

4A00	INPUT LABELS				
Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
4A11	Opto Input 17				
4A12	Opto Input 18				
4A13	Opto Input 19				
4A14	Opto Input 20				
4A15	Opto Input 21				
4A16	Opto Input 22				
4A17	Opto Input 23				
4A18	Opto Input 24				
4A19	Opto Input 25				
4A1A	Opto Input 26				
4A1B	Opto Input 27				
4A1C	Opto Input 28				
4A1D	Opto Input 29				
4A1E	Opto Input 30				
4A1F	Opto Input 31				
4A20	Opto Input 32				

4B00	OUTPUT LABELS				
Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
4B01	Relay 1				
4B02	Relay 2				
4B03	Relay 3				
4B04	Relay 4				
4B05	Relay 5				
4B06	Relay 6				
4B07	Relay 7				
4B08	Relay 8				
4B09	Relay 9				
4B0A	Relay 10				
4B0B	Relay 11				
4B0C	Relay 12				
4B0D	Relay 13				
4B0E	Relay 14				
4B0F	Relay 15				
4B10	Relay 16				
4B11	Relay 17				
4B12	Relay 18				
4B13	Relay 19				
4B14	Relay 20				
4B15	Relay 21				
4B16	Relay 22				
4B17	Relay 23				

4B00	OUTPUT LABELS				
Group 1 Settings		Group 1 Settings	Group 2 Settings	Group 3 Settings	Group 4 Settings
4B18	Relay 24				
4B19	Relay 25				
4B1A	Relay 26				
4B1B	Relay 27				
4B1C	Relay 28				
4B1D	Relay 29				
4B1E	Relay 30				
4B1F	Relay 31				
4B20	Relay 32				

Commissioning Engineer

Date:

Customer Witness

Date:

MAINTENANCE

CHAPTER 11

Date:	10/2012	
Products covered by this chapter:	P14x (P141, P142, P143, P144 & P145), P445, P44y (P443 and P446), P547, P54x (P543, P544, P545 & P546), P841, P842 and P846	
Hardware suffix:	P14x (P141, P142, P143, P144 & P145)	J
	P445	J
	P44y (P443 and P446)	K
	P547	K
	P54x (P543, P544, P545 & P546)	K
	P642	J
	P643	K
	P645	K
	P841	K
	P842	B
	P846	J
Software version:	P14x (P141, P142, P143, P144 & P145)	43
	P445	35 & 36
	P44y (P443 and P446)	0550
	P547	57
	P54x (P543, P544, P545 & P546)	45 & 55
	P64x (P642, P643 & P645)	04
	P841	45 & 55
	P842	04
	P846	30
Connection diagrams:	P14x (P141, P142, P143, P144 & P145): 10P141/2/3/4/5xx (xx = 01 to 07) P445: 10P445xx (xx = 01 to 04) P44y: 10P44303 (SH 01 and 03) 10P44304 (SH 01 and 03) 10P44305 (SH 01 and 03) 10P44306 (SH 01 and 03) 10P44600 10P44601 (SH 1 to 2) 10P44602 (SH 1 to 2) 10P44603 (SH 1 to 2) P54x (P543, P544, P545 & P546): 10P54302xx (xx = 01 to 02) 10P54303xx (xx = 01 to 02) 10P54400 10P54402xx (xx = 01 to 02) 10P54403xx (xx = 01 to 02) 10P54502xx (xx = 01 to 02) 10P54503xx (xx = 01 to 02) 10P54600 10P54602xx (xx = 01 to 02) 10P54603xx (xx = 01 to 02)	P547: 10P54702xx (xx = 01 to 02) 10P54703xx (xx = 01 to 02) 10P54704xx (xx = 01 to 02) 10P54705xx (xx = 01 to 02) P64x (P642, P643 & P645): 10P642xx (xx = 01 to 10) 10P643xx (xx = 01 to 6) 10P644xx (xx = 01 to 9) P841: 10P84100 10P84101 (SH 1 to 2) 10P84102 (SH 1 to 2) 10P84103 (SH 1 to 2) 10P84104 (SH 1 to 2) 10P84105 (SH 1 to 2) P842: 10P842xx (xx = 01 to 02) P846: 10P846xx (xx = 01 to 07)

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Notes:

1 MAINTENANCE PERIOD

It is recommended that products supplied by Schneider Electric receive periodic monitoring after installation. In view of the critical nature of protective and control equipment, and their infrequent operation, it is desirable to confirm that they are operating correctly at regular intervals.

Schneider Electric protection and control equipment is designed for a life in excess of 20 years.

MiCOM relays are self-supervizing and so require less maintenance than earlier designs. Most problems will result in an alarm so that remedial action can be taken. However, some periodic tests should be done to ensure that the equipment is functioning correctly and the external wiring is intact.

If the customer's organization has a preventative maintenance policy, the recommended product checks should be included in the regular program. Maintenance periods depend on many factors, such as:

- The operating environment
- The accessibility of the site
- The amount of available manpower
- The importance of the installation in the power system
- The consequences of failure

2 MAINTENANCE CHECKS

Although some functionality checks can be performed from a remote location by using the communications ability of the equipment, these are predominantly restricted to checking that the equipment, is measuring the applied currents and voltages accurately, and checking the circuit breaker maintenance counters. Therefore it is recommended that maintenance checks are performed locally (i.e. at the equipment itself).

Warning **Before carrying out any work on the equipment, the user should be familiar with the contents of the Safety Guide or the Technical Data chapter of this Technical Manual and also the ratings on the equipment's rating label.**

2.1 Alarms

The alarm status LED should first be checked to identify if any alarm conditions exist. If so, press the read key [📖] repeatedly to step through the alarms.

Clear the alarms to extinguish the LED.

2.2 Opto-Isolators

The opto-isolated inputs can be checked to ensure that the equipment responds to energization by repeating the commissioning test detailed in the Commissioning chapter.

2.3 Output Relays

The output relays can be checked to ensure that they operate by repeating the commissioning test detailed in the Commissioning chapter.

2.4 Measurement Accuracy

If the power system is energized, the values measured by the equipment can be compared with known system values to check that they are in the approximate range that is expected. If they are, the analog/digital conversion and calculations are being performed correctly by the relay. Suitable test methods can be found in the Commissioning chapter.

Alternatively, the values measured by the equipment can be checked against known values injected via the test block, if fitted, or injected directly into the equipment terminals. Suitable test methods can be found in the Commissioning chapter. These tests will prove the calibration accuracy is being maintained.

3 METHOD OF REPAIR

If the equipment should develop a fault whilst in service, depending on the nature of the fault, the watchdog contacts will change state and an alarm condition will be flagged. Due to the extensive use of surface-mount components, faulty Printed Circuit Boards (PCBs) should be replaced, as it is not possible to perform repairs on damaged PCBs. Therefore either the complete equipment module or just the faulty PCB (as identified by the in-built diagnostic software), can be replaced. Advice about identifying the faulty PCB can be found in the Troubleshooting chapter.

The preferred method is to replace the complete equipment module as it ensures that the internal circuitry is protected against electrostatic discharge and physical damage at all times and overcomes the possibility of incompatibility between replacement PCBs. However, it may be difficult to remove installed equipment due to limited access in the back of the cubicle and the rigidity of the scheme wiring.

Replacing PCBs can reduce transport costs but requires clean, dry conditions on site and higher skills from the person performing the repair. If the repair is not performed by an approved service center, the warranty will be invalidated.

Warning **Before carrying out any work on the equipment, the user should be familiar with the contents of the Safety Guide or the Technical Data chapter of this Technical Manual and also the ratings on the equipment's rating label.**

This should ensure that no damage is caused by incorrect handling of the electronic components.

3.1 Replacing the Complete Equipment IED/Relay

The case and rear terminal blocks have been designed to facilitate removal of the IED/relay should replacement or repair become necessary without having to disconnect the scheme wiring.

Warning **Before working at the rear of the equipment, isolate all voltage and current supplies to the equipment.**

Note *The MiCOM range has integral current transformer shorting switches which will close when the heavy duty terminal block is removed.*

1. Disconnect the equipment's earth, IRIG-B and fiber optic connections, as appropriate, from the rear of the device.

   There are two types of terminal block used on the equipment, medium and heavy duty, which are fastened to the rear panel using crosshead screws. The P64x range also includes an RTD/CLIO terminal block option. These block types are shown in the Commissioning chapter.

Important *The use of a magnetic bladed screwdriver is recommended to minimize the risk of the screws being left in the terminal block or lost.*

2. Without exerting excessive force or damaging the scheme wiring, pull the terminal blocks away from their internal connectors.
3. Remove the screws used to fasten the equipment to the panel, rack, etc. These are the screws with the larger diameter heads that are accessible when the access covers are fitted and open.

Warning **If the top and bottom access covers have been removed, do not remove the screws with the smaller diameter heads which are accessible. These screws secure the front panel to the equipment.**

4. Withdraw the equipment carefully from the panel, rack, etc. because it will be heavy due to the internal transformers.

To reinstall the repaired or replacement equipment, follow the above instructions in reverse, ensuring that each terminal block is relocated in the correct position and the case earth, IRIG-B and fiber optic connections are replaced. To facilitate easy identification of each terminal block, they are labeled alphabetically with 'A' on the left-hand side when viewed from the rear.

Once reinstallation is complete, the equipment should be re-commissioned using the instructions in the Commissioning chapter.

3.2 Replacing a PCB

Replacing PCBs and other internal components must be undertaken only by Service Centers approved by Schneider Electric. Failure to obtain the authorization of Schneider Electric after sales engineers prior to commencing work may invalidate the product warranty.

Warning **Before removing the front panel to replace a PCB, remove the auxiliary supply and wait at least 30 seconds for the capacitors to discharge.**
We strongly recommend that the voltage and current transformer connections and trip circuit are isolated.

Schneider Electric support teams are available world-wide. We strongly recommend that any repairs be entrusted to those trained personnel. For this reason, details on product disassembly and re-assembly are not included here.

4 RE-CALIBRATION

Re-calibration is not required when a PCB is replaced **unless it happens to be one of the boards in the input module;** the replacement of either directly affects the calibration.

Warning	**Although it is possible to carry out re-calibration on site, this requires test equipment with suitable accuracy and a special calibration program to run on a PC. It is therefore recommended that the work be carried out by the manufacturer, or entrusted to an approved service center.**

5 CHANGING THE BATTERY

Each relay/IED has a battery to maintain status data and the correct time when the auxiliary supply voltage fails. The data maintained includes event, fault and disturbance records and the thermal state at the time of failure.

This battery will periodically need changing, although an alarm will be given as part of the relay's/IED's continuous self-monitoring in the event of a low battery condition.

If the battery-backed facilities are not required to be maintained during an interruption of the auxiliary supply, the steps below can be followed to remove the battery, but do not replace with a new battery.

Warning **Before carrying out any work on the equipment, the user should be familiar with the contents of the Safety Guide or the Technical Data chapter of this Technical Manual and also the ratings on the equipment's rating label.**

5.1 Instructions for Replacing the Battery

1. Open the bottom access cover on the front of the equipment.
2. Gently extract the battery from its socket. If necessary, use a small, insulated screwdriver to prize the battery free.
3. Ensure that the metal terminals in the battery socket are free from corrosion, grease and dust.
4. The replacement battery should be removed from its packaging and placed into the battery holder, taking care to ensure that the polarity markings on the battery agree with those adjacent to the socket.

Note *Only use a type ½AA Lithium battery with a nominal voltage of 3.6 V and safety approvals such as UL (Underwriters Laboratory), CSA (Canadian Standards Association) or VDE (Vereinigung Deutscher Elektrizitätswerke).*

5. Ensure that the battery is securely held in its socket and that the battery terminals are making good contact with the metal terminals of the socket.
6. Close the bottom access cover.

5.2 Post Modification Tests

To ensure that the replacement battery will maintain the time and status data if the auxiliary supply fails, check cell [0806: DATE and TIME, Battery Status] reads 'Healthy'.

If further confirmation that the replacement battery is installed correctly is required, the commissioning test is described in the Commissioning chapter, 'Date and Time', can be performed.

5.3 Battery Disposal

The battery that has been removed should be disposed of in accordance with the disposal procedure for Lithium batteries in the country in which the equipment is installed.

6 CLEANING

Warning **Before cleaning the equipment ensure that all ac and dc supplies, current transformer and voltage transformer connections are isolated to prevent any chance of an electric shock whilst cleaning.**

The equipment may be cleaned using a lint-free cloth moistened with clean water. The use of detergents, solvents or abrasive cleaners is not recommended as they may damage the relay’s surface and leave a conductive residue.

TROUBLESHOOTING

CHAPTER 12

Date:	November 2011	
Hardware Suffix:	P14x (P141, P142, P143, P144 & P145)	J
	P24x (P241, P242 & P243)	J (P241) & K (P242/P243)
	P341	J
	P34x (P342, P343, P344, P345 & P346)	J (P342) K (P343/P344/P345/P346) A (P391)
	P391	A
	P445	J
	P44y (P443 and P446)	K
	P547	K
	P54x (P543, P544, P545 & P546)	K
	P64x (P642, P643 & P645):	J (P642) & K (P643/645)
	P841	K
	P842	B
	P846	J
Software Version:	P14x (P141, P142, P143, P144 & P145)	43
	P24x (P241, P242 & P243)	57
	P341	36 & 71 (with DLR)
	P34x (P342, P343, P344, P345 & P346)	36
	P391	36
	P445	35 & 36
	P44y (P443 and P446)	0550
	P547	57
	P54x (P543, P544, P545 & P546)	45 & 55
	P64x (P642, P643 & P645):	04
	P841	45 & 55
	P842	04
	P846	30
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Notes:

1 INTRODUCTION

Warning	**Before carrying out any work on the equipment, the user should be familiar with the contents of the Safety Guide or the Technical Data chapter of this Technical Manual and also the ratings on the equipment's rating label.**

The purpose of this chapter of the service manual is to allow an error condition on the relay to be identified so that appropriate corrective action can be taken.

If the relay has developed a fault, it should be possible in most cases to identify which relay module requires attention. The *Maintenance* chapter advises on the recommended method of repair where faulty modules need replacing. It is not possible to perform an on-site repair to a faulted module.

In cases where a faulty relay/module is being returned to the manufacturer or one of their approved service centers, completed copy of the Repair/Modification Return Authorization Form located at the end of this chapter should be included.

2 INITIAL PROBLEM IDENTIFICATION

Consult Table 1 to find the description that best matches the problem experienced, then consult the section referenced to perform a more detailed analysis of the problem.

Symptom	Refer To
Relay fails to power up	Section 4
Relay powers up - but indicates error and halts during power-up sequence	Section 5
Relay Powers up but Out of Service LED is illuminated	Section 6
Error during normal operation	Section 7
Mal-operation of the relay during testing	Section 8

Table 1 - Problem identification

3 POWER UP ERRORS

If the relay does not appear to power up then the following procedure can be used to determine whether the fault is in the external wiring, auxiliary fuse, power supply module of the relay or the relay front panel.

Test	Check	Action
1	Measure auxiliary voltage on terminals 1 and 2; verify voltage level and polarity against rating the label on front. Terminal 1 is –dc, 2 is +dc	If auxiliary voltage is present and correct, then proceed to test 2. Otherwise the wiring/fuses in auxiliary supply should be checked.
2	Do LEDs/and LCD backlight illuminate on power-up, also check the N/O watchdog contact for closing.	If they illuminate or the contact closes and no error code is displayed then error is probably in the main processor board (front panel). If they do not illuminate and the contact does not close then proceed to test 3.
3	Check Field voltage output (nominally 48V DC)	If field voltage is not present then the fault is probably in the relay power supply module.

Table 2 - Failure of relay to power up

4 ERROR MESSAGE/CODE ON POWER-UP

During the power-up sequence of the relay self-testing is performed as indicated by the messages displayed on the LCD. If an error is detected by the relay during these self-tests, an error message will be displayed and the power-up sequence will be halted. If the error occurs when the relay application software is executing, a maintenance record will be created and the relay will reboot.

Test	Check	Action
1	Is an error message or code permanently displayed during power up?	If relay locks up and displays an error code permanently then proceed to test 2. If the relay prompts for input by the user proceed to test 4. If the relay re-boots automatically then proceed to test 5
2	Record displayed error, then remove and re-apply relay auxiliary supply.	Record whether the same error code is displayed when the relay is rebooted. If no error code is displayed then contact the local service center stating the error code and relay information. If the same code is displayed proceed to test 3.
3	Error code Identification Following text messages (in English) will be displayed if a fundamental problem is detected preventing the system from booting: Bus Fail address lines SRAM Fail data lines FLASH Fail format error FLASH Fail checksum Code Verify Fail These hex error codes relate to errors detected in specific relay modules:	These messages indicate that a problem has been detected on the main processor board of the relay (located in the front panel).
	0c140005/0c0d0000	Input Module (inc. Opto-isolated inputs)
	0c140006/0c0e0000	Output Relay Cards
	Last 4 digits provide details on the actual error.	Other error codes relate to problems within the main processor board hardware or software. It will be necessary to contact Schneider Electric with details of the problem for a full analysis.
4	Relay displays message for corrupt settings and prompts for restoration of defaults to the affected settings.	The power up tests have detected corrupted relay settings, it is possible to restore defaults to allow the power-up to be completed. It will then be necessary to re-apply the application-specific settings.
5	Relay resets on completion of power up - record error code displayed	Error 0x0E080000, Programmable Scheme Logic (PSL) error due to excessive execution time. Restore default settings by performing a power up with ⇦ and ⇨ keys depressed, confirm restoration of defaults at prompt using (↵) key. If relay powers up successfully, check PSL for feedback paths. Other error codes will relate to software errors on the main processor board, contact Schneider Electric.

Table 3 - Power-up self-test error

5 OUT OF SERVICE LED ILLUMINATED ON POWER UP

Test	Check	Action	
1	Using the relay menu confirm whether the Commission Test/Test Mode setting is Enabled. Otherwise proceed to test 2.	If the setting is Enabled then disable the test mode and, verify that the Out of Service LED is extinguished.	
2	Select and view the last maintenance record from the menu (in the View Records).	Check for H/W Verify Fail this indicates a discrepancy between the relay model number and the hardware; examine the “**Maint. Data**”, this indicates the causes of the failure using bit fields:	
		Bit	**Meaning**
		0	The application type field in the model number does not match the software ID
		1	The application field in the model number does not match the software ID
		2	The variant 1 field in the model number does not match the software ID
		3	The variant 2 field in the model number does not match the software ID
		4	The protocol field in the model number does not match the software ID
		5	The language field in the model number does not match the software ID
		6	The VT type field in the model number is incorrect (110V VTs fitted)
		7	The VT type field in the model number is incorrect (440V VTs fitted)
		8	The VT type field in the model number is incorrect (no VTs fitted)

Table 4 - Out of service LED illuminated

6 ERROR CODE DURING OPERATION

The relay performs continuous self-checking, if an error is detected then an error message will be displayed, a maintenance record will be logged and the relay will reset (after a 1.6 second delay). A permanent problem (for example due to a hardware fault) will generally be detected on the power up sequence, following which the relay will display an error code and halt. If the problem was transient in nature then the relay should reboot correctly and continue in operation. The nature of the detected fault can be determined by examination of the maintenance record logged.

There are also two cases where a maintenance record will be logged due to a detected error where the relay will not reset. These are detection of a failure of either the field voltage or the lithium battery, in these cases the failure is indicated by an alarm message, however the relay will continue to operate.

If the field voltage is detected to have failed (the voltage level has dropped below threshold), then a scheme logic signal is also set. This allows the scheme logic to be adapted in the case of this failure (for example if a blocking scheme is being used).

In the case of a battery failure it is possible to prevent the relay from issuing an alarm using the setting under the Date and Time section of the menu. This setting ‘**Battery Alarm**’ can be set to '**Disabled**' to allow the relay to be used without a battery, without an alarm message being displayed.

In the case of an RTD board failure, an alarm "RTD board fail" message is displayed, the RTD protection is disabled, but the operation of the rest of the relay functionality is unaffected.

7 MAL-OPERATION OF THE RELAY DURING TESTING

7.1 Failure of Output Contacts

An apparent failure of the relay output contacts may be caused by the relay configuration; the following tests should be performed to identify the real cause of the failure.

Note *The relay self-tests verify that the coil of the contact has been energized, an error will be displayed if there is a fault in the output relay board.*

Test	Check	Action
1	Is the Out of Service LED illuminated?	Illumination of this LED may indicate that the relay is in test mode or that the protection has been disabled due to a hardware verify error (see Table 4).
2	Examine the Contact status in the Commissioning section of the menu.	If the relevant bits of the contact status are operated, proceed to test 4, if not proceed to test 3.
3	Verify by examination of the fault record or by using the test port whether the protection element is operating correctly.	If the protection element does not operate verify whether the test is being correctly applied. If the protection element does operate, it will be necessary to check the PSL to ensure that the mapping of the protection element to the contacts is correct.
4	Using the Commissioning/Test mode function apply a test pattern to the relevant relay output contacts and verify whether they operate (note the correct external connection diagram should be consulted). A continuity tester can be used at the rear of the relay for this purpose.	If the output relay does operate, the problem must be in the external wiring to the relay. If the output relay does not operate this could indicate a failure of the output relay contacts (note that the self-tests verify that the relay coil is being energized). Ensure that the closed resistance is not too high for the continuity tester to detect.

Table 5 - Failure of output contacts

7.2 Failure of Opto-Isolated Inputs

The opto-isolated inputs are mapped onto the relay internal signals using the PSL. If an input does not appear to be recognized by the relay scheme logic the Commission Tests/Opto Status menu option can be used to verify whether the problem is in the opto-isolated input itself or the mapping of its signal to the scheme logic functions. If the opto-isolated input does appear to be read correctly then it will be necessary to examine its mapping within the PSL.

Ensure the voltage rating for the opto inputs has been configured correctly with applied voltage. If the opto-isolated input state is not being correctly read by the relay the applied signal should be tested. Verify the connections to the opto-isolated input using the correct wiring diagram and the correct nominal voltage settings in any standard or custom menu settings. Next, using a voltmeter verify that 80% opto setting voltage is present on the terminals of the opto-isolated input in the energized state. If the signal is being correctly applied to the relay then the failure may be on the input card itself. Depending on which opto-isolated input has failed this may require replacement of either the complete analog input module (the board within this module cannot be individually replaced without re-calibration of the relay) or a separate opto board.

7.3 Incorrect Analog Signals

The measurements may be configured in primary or secondary to assist. If it is suspected that the analog quantities being measured by the relay are not correct then the measurement function of the relay can be used to verify the nature of the problem. The measured values displayed by the relay should be compared with the actual magnitudes at the relay terminals. Verify that the correct terminals are being used (in particular the dual rated CT inputs) and that the CT and VT ratios set on the relay are correct. The correct 120 degree displacement of the phase measurements should be used to confirm that the inputs have been correctly connected.

7.4 PSL Editor Troubleshooting

A failure to open a connection could be because of one or more of the following:

- The relay address is not valid (note: this address is always 1 for the front port).
- Password is not valid
- Communication Set-up - COM port, Baud rate, or Framing - is not correct
- Transaction values are not suitable for the relay and/or the type of connection
- Modem configuration is not valid. Changes may be necessary when using a modem
- The connection cable is not wired correctly or broken. See MiCOM S1 connection configurations
- The option switches on any KITZ101/102 that is in use may be incorrectly set

7.4.1 Diagram Reconstruction after Recover from Relay

Although the extraction of a scheme from a relay is supported, the facility is provided as a way of recovering a scheme in the event that the original file is unobtainable.

The recovered scheme will be logically correct, but much of the original graphical information is lost. Many signals will be drawn in a vertical line down the left side of the canvas. Links are drawn orthogonally using the shortest path from A to B.

Any annotation added to the original diagram (titles, notes, etc.) are lost.

Sometimes a gate type may not be what was expected, e.g. a 1-input AND gate in the original scheme will appear as an OR gate when uploaded. Programmable gates with an inputs-to-trigger value of 1 will also appear as OR gates.

7.4.2 PSL Version Check

The PSL is saved with a version reference, time stamp and CRC check. This gives a visual check whether the default PSL is in place or whether a new application has been downloaded.

8 REPAIR AND MODIFICATION PROCEDURE

Please follow these steps to return an Automation product to us:

1. Get the Repair and Modification Authorization Form (RMA).

   A copy of the RMA form is shown at the end of this section.

2. Fill in the RMA form.

   Fill in only the white part of the form.

   Please ensure that all fields marked **(M)** are completed such as:

   Equipment model

   Model No. and Serial No.

   Description of failure or modification required (please be specific)

   Value for customs (in case the product requires export)

   Delivery and invoice addresses

   Contact details

3. Receive from local service contact, the information required to ship the product.

   Your local service contact will provide you with all the information:

   Pricing details

   RMA No

   Repair center address

   If required, an acceptance of the quote must be delivered before going to next stage.

4. Send the product to the repair center.

   Address the shipment to the repair center specified by your local contact.

   Ensure all items are protected by appropriate packaging: anti-static bag and foam protection.

   Ensure a copy of the import invoice is attached with the unit being returned.

   Ensure a copy of the RMA form is attached with the unit being returned.

   E-mail or fax a copy of the import invoice and airway bill document to your local contact.

Notes:

Schneider Electric

REPAIR/MODIFICATION RETURN AUTHORIZATION FORM

FIELDS IN GREY TO BE FILLED IN BY SCHNEIDER ELECTRIC PERSONNEL ONLY

Reference **RMA:** _____		Date:
Repair Center Address (for shipping)	**Service Type** ☐ Retrofit ☐ Warranty ☐ Paid service ☐ Under repair contract ☐ Wrong supply	LSC PO No.:
Schneider Electric - Local Contact Details Name: Telephone No.: Fax No.: E-mail:		

IDENTIFICATION OF UNIT

Fields marked (M) are mandatory, delays in return will occur if not completed.

Model No./Part No.: **(M)**	Site Name/Project:
Manufacturer Reference: **(M)**	Commissioning Date:
Serial No.: **(M)**	Under Warranty: ☐ Yes ☐ No
Software Version:	Additional Information:
Quantity:	Customer P.O (if paid):

FAULT INFORMATION

Type of Failure	**Found Defective**
Hardware fail ☐	During FAT/inspection ☐
Mechanical fail/visible defect ☐	On receipt ☐
Software fail ☐	During installation/commissioning ☐
Other:	During operation ☐
	Other:
Fault Reproducibility	
Fault persists after removing, checking on test bench ☐	
Fault persists after re-energization ☐	
Intermittent fault ☐	

Description of Failure Observed or Modification Required - *Please be specific* **(M)**

FOR REPAIRS ONLY

Would you like us to install an updated firmware version after repair? ☐ Yes ☐ No

CUSTOMS & INVOICING INFORMATION

Required to allow return of repaired items

Value for Customs (M)	
Customer Invoice Address ((M) if paid)	**Customer Return Delivery Address (full street address) (M)** Part shipment accepted ☐ Yes ☐ No **OR** Full shipment required ☐ Yes ☐ No
Contact Name: Telephone No.: Fax No.: E-mail:	Contact Name: Telephone No.: Fax No.: E-mail:

REPAIR TERMS

1. **Please ensure that a copy of the import invoice is attached with the returned unit, together with the airway bill document.** Please fax/e-mail a copy of the appropriate documentation **(M)**.
2. Please ensure the Purchase Order is released, for paid service, to allow the unit to be shipped.
3. Submission of equipment to Schneider Electric is deemed as authorization to repair and acceptance of quote.
4. Please ensure all items returned are marked as Returned for 'Repair/Modification' and **protected by appropriate packaging** (anti-static bag for each board and foam protection).

SCADA COMMUNICATIONS

CHAPTER 13

Date:	02/2013
Hardware Suffix:	J (P445) and K (P443/P446, P543/P544/P545/P546 and P547)
Software Version:	35, 36 (P445), 45 (P543/P544/P545/P546 without Distance), 55 (P443/P446/P543/P544/P545/P546 with Distance), 57 (P547), B0 (P443/P446/P543/P544/P545 & P546) and E0 (P445)
Connection Diagrams:	10P44303 (SH 01 and 03) 10P44304 (SH 01 and 03) 10P44305 (SH 01 and 03) 10P44306 (SH 01 and 03)
	10P44600 10P44601 (SH 1 to 2) 10P44602 (SH 1 to 2) 10P44603 (SH 1 to 2)
	10P445xx (xx = 01 to 04)
	10P54302 (SH 1 to 2) 10P54303 (SH 1 to 2)
	10P54400 10P54404 (SH 1 to 2) 10P54405 (SH 1 to 2)
	10P54502 (SH 1 to 2) 10P54503 (SH 1 to 2)
	10P54600 10P54604 (SH 1 to 2) 10P54605 (SH 1 to 2) 10P54606 (SH 1 to 2)
	10P54702xx (xx = 01 to 02) 10P54703xx (xx = 01 to 02) 10P54704xx (xx = 01 to 02) 10P54705xx (xx = 01 to 02)

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Notes:

1 INTRODUCTION

This chapter outlines the remote communications interfaces of the relay in enough detail to allow integration in a substation communication network. The relay supports a choice of one of several protocols via a rear 2-wire EIA(RS)485 communication interface (RP1), selected via the model number when ordering. According to the protocol and hardware options selected, the interface may be presented over an optical fiber interface or an Ethernet connection. The protocols supported by the first rear communications port (RP1) are:

- Courier
- IEC 60870-5-103
- DNP3.0

The protocol implemented in the relay can be checked in the relay menu in the 'COMMUNICATIONS' column. Using the keypad and LCD, firstly check that the 'Comms. Settings' cell in the 'CONFIGURATION' column is set to 'Visible', then move to the 'COMMUNICATIONS' column. The first cell down the column shows the communication protocol being used by the rear port.

Note	*The IEC 60870-5-103 standard is sometimes abbreviated to IEC 870-5-103, IEC 60870, or even -103. It may be described as the 'VDEW' standard.*

The Courier rear port interface may present as EIA(RS)485, or, using the same connection, it may present a K-Bus standard compliant interface.

The rear port (RP1), is complemented by the front serial interface, and an optional second rear communications interface, RP2, both of which have fixed protocol support for Courier only.

The implementation of both Courier and IEC 60870-5-103 on RP1 can also, optionally, be presented over fiber as well as EIA(RS)485. The DNP3.0 implementation is available via the EIA(RS)485 port and an additional Ethernet implementation is also available as an option.

All rear port communication interfaces are fully isolated and suitable for permanent connection. EIA(RS)485 (and K-Bus) connections allow up to 32 devices to be 'daisy-chained' together using a simple twisted pair electrical connection.

Note	*The second rear Courier port, the fiber optic interface, and the DNP3.0 over Ethernet are mutually exclusive as they occupy the same physical slot.*

For each of the communications ports an outline of the connection details is provided in this section. The ports are configurable using settings - a description of the configuration follows the connections part. Details of the protocol characteristics are shown too.

The protocol characteristics described here are specific to the implementation of the protocol in the relay. They are not exhaustive. Further information is provided in:

R6509	K-Bus interface Guide
R5610	IEC 60870 Interface Guide
R6511	Courier Protocol
R6512	Courier User Guide
www.dnp.org	

Details of the physical connections to the interfaces is in the Installation (IN) chapter.

2 COMMUNICATIONS PORTS

2.1 Connections to the Communications Ports

2.1.1 Connections to the Front Port

The front communications port is not intended for permanent connection. The front communications port supports the Courier protocol and is implemented on an EIA(RS)232 connection. A 9-pin connector type, as described in the *Getting Started* chapter of this manual, is used, and the cabling requirements are detailed in the *Installation* chapter of this manual.

2.1.2 Connections to the EIA(RS)485 Rear Port, RP1

The rear EIA(RS)485 communication port is provided by a 3-terminal screw connector located on the back of the relay. See the Installation chapter of this manual for details of the connection terminals. The rear port provides 2-wire EIA(RS)485 serial data communication and is intended for use with a permanently wired connection. Of the three terminals on the connection, two are for the signal connection, and the other is for the earth shield of the cable.

If the IEC60870-5-103, or the DNP3.0 protocols are specified as the interface for the rear port, then connections conform entirely to the EIA(RS)485 standards outline below. If, however, the Courier protocol is specified as the rear port protocol, then the interface can be set either to EIA(RS)485 or K-Bus. The configuration of the port as either EIA(RS)485 or K-Bus is described later together with K-Bus details, but as connection to the port is affected by this choice, the following points should be noted:

- Connection to an EIA(RS)485 device is polarity sensitive, whereas K-Bus connection is not.
- Whilst connection to between an EIA(RS)485 port and an EIA(RS)232 port on, say, a PC might be implemented using a general purpose EIA(RS)485 to EIA(RS)232 converter, connection between an EIA(RS)232 port and K-Bus requires a KITZ101, KITZ102 or KITZ201

Unless the K-Bus option is chosen for the rear port, correct polarity must be observed for the signal connections. In all other respects (bus wiring, topology, connection, biasing and termination) K-Bus can be considered the same as EIA(RS)485.

All rear port communication interfaces are fully isolated and suitable for permanent connection. EIA(RS)485 (and K-Bus) connections allow up to 32 devices to be ‘daisy-chained’ together using a simple twisted pair electrical connection.

2.1.2.1 EIA(RS)485 Bus

The EIA(RS)-485 two-wire connection provides a half-duplex fully isolated serial connection to the product. The connection is polarized and while the product’s connection diagrams show the polarization of the connection terminals, there is no agreed definition of which terminal is which. If the master is unable to communicate with the product and the communication parameters match, make sure the two-wire connection is not reversed.

2.1.2.2 EIA(RS)485 Bus Termination

The EIA(RS)485 bus must have 120Ω (Ohm) ½ Watt terminating resistors fitted at either end across the signal wires - see Figure 1. Some devices may be able to provide the bus terminating resistors by different connection or configuration arrangements, in which case separate external components are not required. However, this product does not provide such a facility, so if it is located at the bus terminus, an external termination resistor is needed.

2.1.2.3 EIA(RS)485 Bus Connections and Topologies

The EIA(RS)485 standard requires that each device be directly connected to the physical cable that is the communications bus. Stubs and tees are expressly forbidden, as are star topologies. Loop bus topologies are not part of the EIA(RS)485 standard and are forbidden by it.

Two-core screened cable is recommended. The cable specification depends on the application, although a multi-strand 0.5 mm^2 per core is normally adequate. Total cable length must not exceed 1000 m. The screen must be continuous and connected to ground at one end, normally at the master connection point. It is important to avoid circulating currents, especially when the cable runs between buildings, for both safety and noise reasons.

This product does not provide a signal ground connection. If a signal ground connection is present in the bus cable then it must be ignored, although it must have continuity for the benefit of other devices connected to the bus. At no stage must the signal ground be connected to the cables screen or to the products chassis. This is for both safety and noise reasons.

2.1.2.4 EIA(RS)485 Biasing

It may also be necessary to bias the signal wires to prevent jabber. Jabber occurs when the signal level has an indeterminate state because the bus is not being actively driven. This can occur when all the slaves are in receive mode and the master is slow to turn from receive mode to transmit mode. This may be because the master purposefully waits in receive mode, or even in a high impedance state, until it has something to transmit. Jabber causes the receiving device(s) to miss the first bits of the first character in the packet, which results in the slave rejecting the message and consequentially not responding. Symptoms of this are poor response times (due to retries), increasing message error counters, erratic communications, and even a complete failure to communicate.

Biasing requires that the signal lines be weakly pulled to a defined voltage level of about 1V. There should only be one bias point on the bus, which is best situated at the master connection point. The DC source used for the bias must be clean; otherwise noise will be injected.

Note *Some devices may (optionally) be able to provide the bus bias, in which case external components will not be required.*

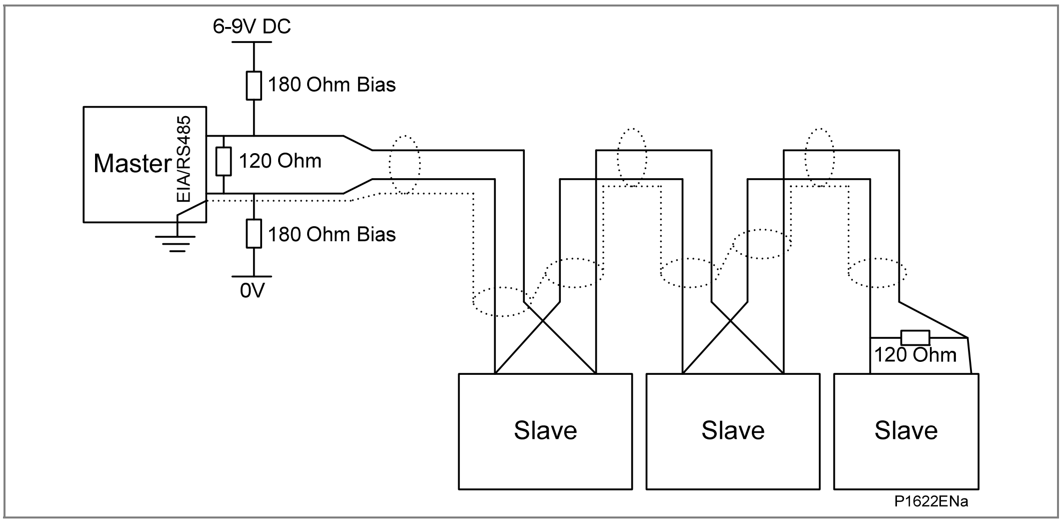


Figure 1 - EIA(RS)485 bus connection arrangements

It is possible to use the product's field voltage output (48 V DC) to bias the bus using values of 2.2 kΩ (½W) as bias resistors instead of the 180 Ω resistors shown in Figure 1.

Warnings

The following warnings apply:
It is extremely important that the 120 Ω termination resistors are fitted. Failure to do so will result in an excessive bias voltage that may damage the devices connected to the bus.
As the field voltage is much higher than that required, Schneider Electric cannot assume responsibility for any damage that may occur to a device connected to the network as a result of incorrect application of this voltage.
Ensure that the field voltage is not being used for other purposes (i.e. powering logic inputs) as this may cause noise to be passed to the communication network.

2.1.2.5 K-Bus Connections

K-Bus is a robust signaling method based on EIA(RS)485 voltage levels. K-Bus incorporates message framing and uses a 64 kbits/s synchronous HDLC protocol with FM0 modulation to increase speed and security. For this reason is not possible to use a standard EIA(RS)232 to EIA(RS)485 converter to connect with K-Bus devices. Nor is it possible to connect K-Bus to an EIA(RS)485 computer port. A KITZ protocol converter needs to be employed for this purpose.

Please consult Schneider Electric for information regarding the specification and supply of KITZ devices.

As K-Bus is implemented on an EIA(RS)485 layer, however the connection details are very similar to those described in the previous sections and a typical connection arrangement, incorporating a KITZ, is shown in Figure 2. As with EIA(RS)485, each spur of the K-Bus twisted pair wiring can be up to 1000 m in length and have up to 32 relays connected to it.

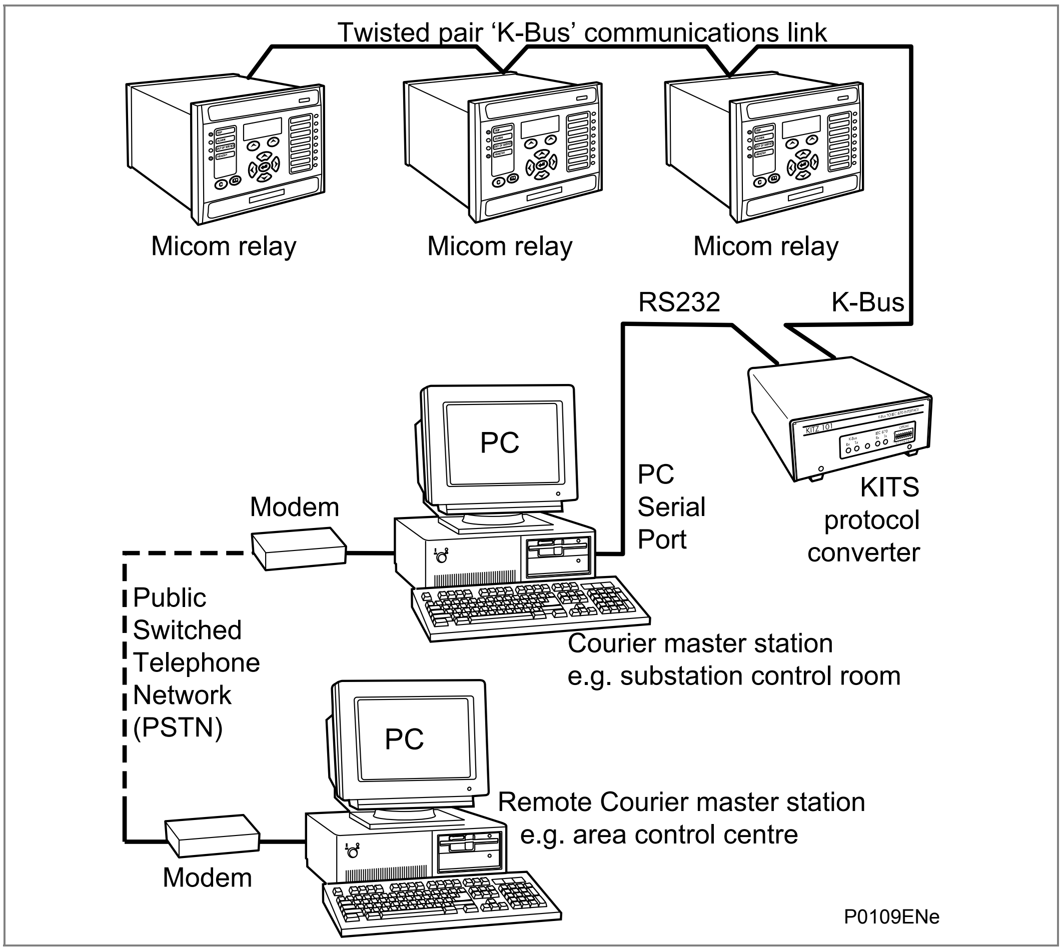

Twisted pair 'K-Bus' communications link
Micom relay
Micom relay
Micom relay
RS232
K-Bus
PC
PC
Serial
Port
KITS
protocol
converter
Modem
Public
Switched
Telephone
Network
(PSTN)
Courier master station
e.g. substation control room
PC
Remote Courier master station
e.g. area control centre
Modem
P0109ENe

Figure 2 - K-Bus connection arrangements

2.1.3 Connections to the Second Rear Communications Port, RP2 (Option)

The second rear communications port supports the Courier protocol only. In a similar manner to the front communications port, connection is made using a 9-pin connector. Unlike the front port implementation, however, it is possible to choose how the interface is physically presented on the second rear communications port. Either EIA(RS)232, EIA(RS)485, or K-Bus may be selected. According to selection, the various connection possibilities described for the front port and the EIA(RS)485 rear port apply.

2.1.4 Connections to the Rear Optical Fiber Port (Option)

The relay can have an optional optical fiber interface in support of the Courier, DNP3.0 and IEC60870-5-103 protocols. Where this is used, connection should be made using either 50/125µm or 62.5/125µm multi-mode optical fibers terminated with BFOC/2.5 (ST) connectors.

2.1.5 Connections to the Ethernet Port (Option)

Connection for Ethernet communication can be made either by standard RJ45 electrical connections or by multi-mode optical fibers suitable for 1300nm transmission and terminated with BFOC/2.5 (ST) connectors.

2.1.6 Connections to the SK5 Port

The lower 9-way D-type connector (SK5) is currently unsupported. Do not connect to this port.

2.2 Configuring the Communications Ports

Courier works on a master/slave basis where the slave units contain information in the form of a database, and respond with information from the database when it is requested by a master unit.

The relay is a slave unit that is designed to be used with a Courier master unit such as MiCOM S1, PAS&T or a SCADA system.

2.2.1 Configuring the Front Courier Port

The front EIA(RS)232 9-pin port supports the Courier protocol for one-to-one communication. It is designed for use during installation, commissioning and maintenance and is not suitable for permanent connection. Since this interface is not intended to link the relay to a substation communication system, not all of the features of the Courier interface are supported. The port is not configurable and the following parameters apply:

• Physical presentation	EIA(RS)232 via 9-pin connector
• Frame format	IEC60870-5 FT1.2 = 11-bit (8 Even 1)
• Address	1
• Baud rate	19200 bps

Note *As part of the limited implementation of Courier on the front port, neither automatic extraction of event and disturbance records, nor busy response are supported.*

2.2.2 Configuring the First Rear Courier Port, RP1

The port is configured using the relay’s communication setting. These are accessed using the front panel user interface keypad, display, and associated menu software.

Once the physical connection is made to the relay, configure the relay’s communication settings using the keypad and LCD user interface.

1. In the relay menu, select the **Configuration** column, then check that the **Comms. settings** cell is set to **Visible**.
2. Select the **Communications** column. Only two settings apply to the rear port using Courier, the relay’s address and the inactivity timer. Synchronous communication uses a fixed baud rate of 64 kbits/s.
3. Move down the **Communications** column from the column heading to the first cell down. This shows the communication protocol.

```
RP1 Protocol
Courier
```

4. The next cell down the column controls the address of the relay. As up to 32 relays can be connected to one K-Bus spur, each relay must have a unique address so messages from the master control station are accepted by one relay only. Courier uses an integer (from 0 to 254) for the relay address that is set with this cell.

Important: no two relays should have the same Courier address. The master station uses the Courier address to communicate with the relay.

```
RP1 Address
1
```

5. The next cell down controls the inactivity timer.

```
RP1 Inactiv timer
10.00 mins.
```

The inactivity timer controls how long the relay waits without receiving any messages on the rear port before it reverts to its default state, including revoking any password access that was enabled. For the rear port this can be set between 1 and 30 minutes.

Note	*Protection and disturbance recorder settings that are modified using an on-line editor such as PAS&T must be confirmed with a write to the 'Save changes' cell of the 'Configuration' column. Off-line editors such as MiCOM S1 Studio do not require this action for the setting changes to take effect.*

The next cell down controls the physical media used for the communication.

```
RP1 Physical link
Copper
```

The default setting is to select the electrical (copper) connection. If the optional fiber optic interface is fitted to the relay, then this setting can be changed to '**Fiber optic**'. This cell is invisible if a second rear communications port or an Ethernet card is fitted, as they are mutually exclusive and occupy the same physical location.

6. If the Physical link selection is copper, the next cell down becomes visible to further define the configuration:

```
RP1 Port Config
KBus
```

The setting choice is between K-Bus and EIA(RS)485. Selecting K-Bus allows connection with K-series devices, but means that a KITZ converter must be used to make a connection. If the EIA(RS)485 selection is made, direct connections can be made to proprietary equipment such as MODEMs. If the EIA(RS)485 selection is made, then two further cells become visible to control the frame format and the communication speed :

7. The frame format is selected in the RP1 Comms mode setting:

```
RP1 Comms Mode
IEC60870 FT1.2
```

The standard default is the IEC 60870-FT1.2. This is an 11-bit framing. Alternatively, a 10-bit framing may be selected for use with MODEMs that do not support 11-bit framing.

8. The final RP1 cell controls the communication speed or baud rate:

```
RP1 Baud Rate
19200 bits/s
```

9. Courier communications is asynchronous and three baud rate selections are available to allow the relay communication rate to be matched to that of the connected equipment. Three baud rates are supported by the relay, '9600 bits/s', '19200 bits/s' and '38400 bits/s'.

2.2.3 Configuring the Second Rear Courier Port, RP2 (Where Fitted)

For relays having the second rear (Courier) communications port fitted, the settings are located immediately below the ones for the first port described above. The second rear communications port only supports the Courier protocol and the settings are similar to those for Courier RP1. The first cell displays:

1. Move down the settings until the following sub heading is displayed.

```
Rear Port 2 (RP2)
```

2. The next cell defines the protocol, which is fixed at Courier for RP2.

```
RP2 protocol
Courier
```

3. The following cell indicates the status of the hardware.

```
RP2 card status
EIA(RS)232 OK
```

4. The following cell allows for selection of the port configuration.

```
RP2 port config.
EIA(RS)232
```

5. The port can be configured for EIA(RS)232, EIA(RS)485 or K-Bus.

   As in the case of the first rear Courier port, if K-Bus is not selected certain other cells to control the communication mode and speed become visible. If either EIA(RS)232 or EIA(RS)485 is selected for the port configuration, the next cell is visible and selects the communication mode.

```
RP2 comms.  Mode
IEC60870 FT1.2
```

6. The standard default is the IEC 60870 FT1.2 for normal operation with 11-bit modems. Alternatively, a 10-bit framing with no parity bit can be selected for special cases.

7. The next cell down sets the communications port address.

```
RP2 address
255
```

   Since up to 32 devices can be connected to one K-bus spur, as indicated in Figure 3, it is necessary for each device to have a unique address so that messages from the master control station are accepted by one device only. Courier uses an integer number between 0 and 254 for the device address that is set with this cell. It is important that no two devices have the same Courier address. The Courier address is then used by the master station to communicate with the device. The default value is 255 and must be changed to a value in the range 0 to 254 before use.

8. The following cell controls the inactivity timer.

```
RP2 InactivTimer
15 mins.
```

9. The inactivity timer controls how long the relay will wait without receiving any messages on the rear port before it reverts to its default state. This includes revoking any password access that was enabled. The inactivity timer can be set between 1 and 30 minutes.

10. If either EIA(RS)232 or EIA(RS)485 is selected for the port configuration, the following cell is visible and selects the communication speed (baud rate):

```
RP2 baud rate
19200
```

11. Courier communications is asynchronous and three selections are available to allow the relay communication rate to be matched to that of the connected equipment. The three baud rates are supported by the relay, ‘9600 bits/s’, ‘19200 bits/s’ and ‘38400 bits/s’.

Figure 3, Figure 4 and Figure 5 show examples of the second rear Courier port configured for application using K-Bus, EIA(RS)485, and EIA(RS)232 respectively.

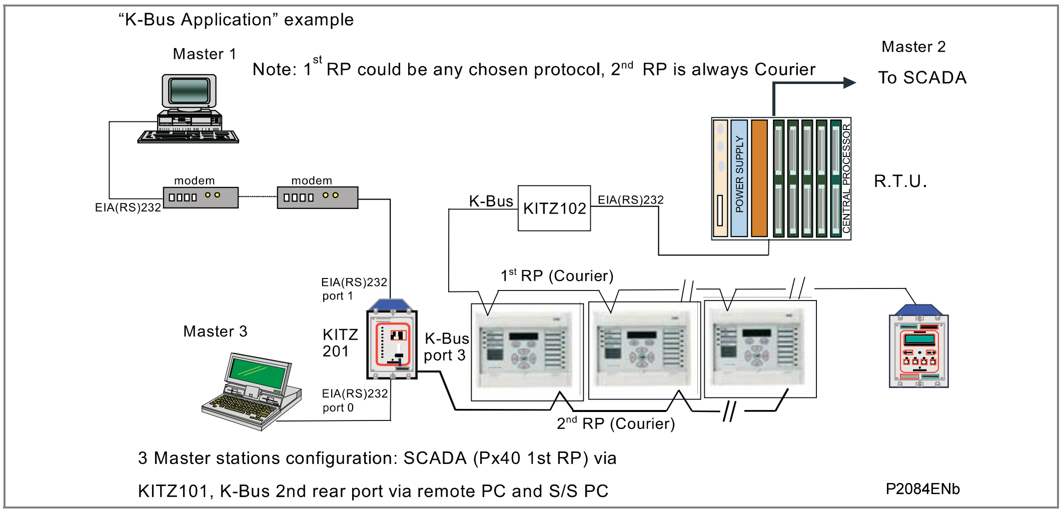

“K-Bus Application” example
Master 1
Note: 1st RP could be any chosen protocol, 2nd RP is always Courier
Master 2
To SCADA
POWER SUPPLY
CENTRAL PROCESSOR
R.T.U.
modem
modem
EIA(RS)232
K-Bus
KITZ102
EIA(RS)232
1st RP (Courier)
EIA(RS)232 port 1
Master 3
KITZ 201
K-Bus port 3
EIA(RS)232 port 0
2nd RP (Courier)
3 Master stations configuration: SCADA (Px40 1st RP) via
KITZ101, K-Bus 2nd rear port via remote PC and S/S PC
P2084ENb

Figure 3 - Second rear port K-Bus application

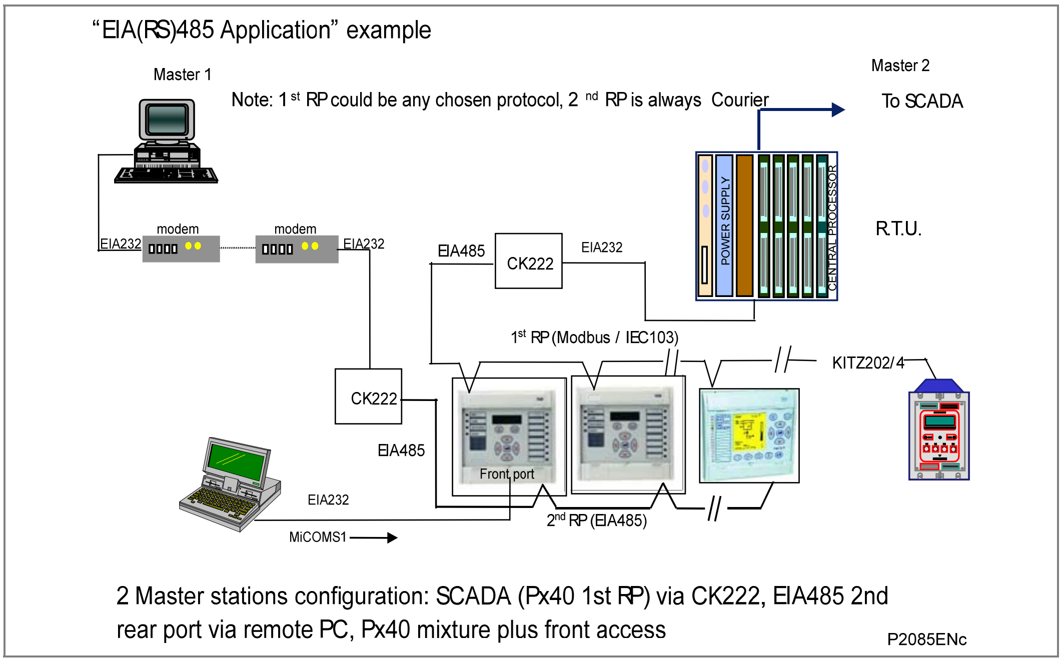
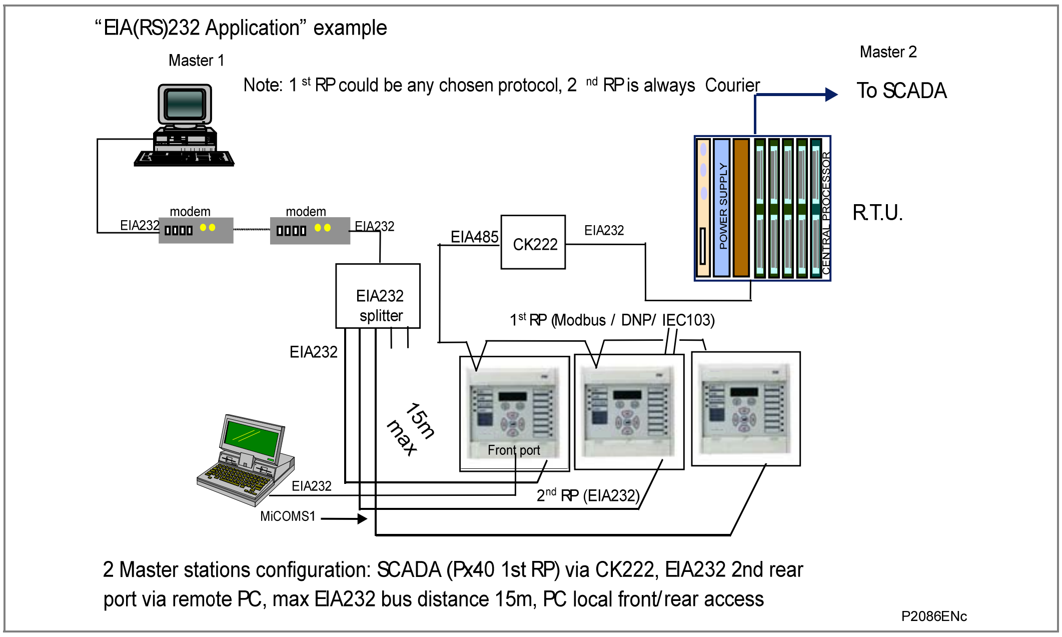

“EIA(RS)485 Application” example
Master 1
Note: 1st RP could be any chosen protocol, 2nd RP is always Courier
Master 2
To SCADA
POWER SUPPLY
CENTRAL PROCESSOR
R.T.U.
EIA232
modem
modem
EIA232
EIA485
CK222
EIA232
1st RP (Modbus / IEC103)
KITZ202/4
CK222
EIA485
Front port
EIA232
MiCOMS1
2nd RP (EIA485)
2 Master stations configuration: SCADA (Px40 1st RP) via CK222, EIA485 2nd
rear port via remote PC, Px40 mixture plus front access
P2085ENc

Figure 4 - Second rear port EIA(RS)485 example


"EIA(RS)232 Application" example
Master 1
Note: 1st RP could be any chosen protocol, 2nd RP is always Courier
Master 2
To SCADA
POWER SUPPLY
CENTRAL PROCESSOR
R.T.U.
modem
modem
EIA232
EIA232
EIA485
CK222
EIA232
EIA232 splitter
1st RP (Modbus / DNP/ IEC103)
EIA232
15m max
Front port
EIA232
2nd RP (EIA232)
MiCOMS1
P2086ENc

2 Master stations configuration: SCADA (Px40 1st RP) via CK222, EIA232 2nd rear port via remote PC, max EIA232 bus distance 15m, PC local front/rear access

Figure 5 - Second rear port EIA(RS)232 example

2.2.4 Configuring the IEC60870-5-103 Rear Port, RP1

The IEC specification IEC 60870-5-103: Telecontrol Equipment and Systems, Part 5: Transmission Protocols Section 103 defines the use of standards IEC 60870-5-1 to IEC 60870-5-5 to perform communication with protection equipment. The standard configuration for the IEC 60870-5-103 protocol is to use a twisted pair EIA(RS)485 connection over distances up to 1000 m. The relay operates as a slave in the system, responding to commands from a master station.

To use the rear port with IEC 60870-5-103 communication, configure the relay's communication settings using the front panel user interface keypad, display, and menu software.

To use the rear port with IEC 60870-5-103 communication, configure the relay's communication settings using the keypad and LCD user interface.

1. In the relay menu, select the **Configuration** column, then check that the **Comms. settings** cell is set to **Visible**.
2. Select the **Communications** column. Four settings apply to the rear port using IEC 60870-5-103 that are described below.

   Move down the 'COMMUNICATIONS' column from the column heading to the first cell to confirm the communication protocol:

   ```
   RP1 Protocol
   IEC60870-5-103
   ```
3. The next cell sets the address of the relay on the IEC 60870-5-103 network:

   ```
   RP1 Address
   162
   ```

   Up to 32 relays can be connected to one IEC 60870-5-103 spur, and therefore it is necessary for each relay to have a unique address so that messages from the master control station are accepted by one relay only. IEC 60870-5-103 uses an integer number between 0 and 254 for the relay address. It is important that no two relays have the same address. The address is then used by the master station to communicate with the relay.

4. The next cell down the column controls the baud rate to be used:

```
RP1 Baud rate
9600 bits/s
```

IEC 60870-5-103 communication is asynchronous. Two baud rates are supported by the relay, '9600 bits/s' and '19200 bits/s'. It is important that whatever baud rate is selected on the relay is the same as that set on the IEC 60870-5-103 master station.

5. The next cell down controls the period between IEC 60870-5-103 measurements:

```
RP1 Meas period
30.00 s
```

The IEC 60870-5-103 protocol allows the relay to supply measurements at regular intervals. The interval between measurements is controlled by this cell, and can be set between 1 and 60 seconds.

6. An optional fiber optic card is available in the relay to allow optical connection to the IEC 60870-5-103 communication to be made over an optical connection. When fitted, it converts between EIA(RS)485 signals and fiber optic signals and the following cell is visible in the menu column:

```
RP1 Physical link
Copper
```

The default setting is to select the electrical (copper) connection. If the optional fiber optic interface is fitted to the relay, then this setting can be changed to 'Fiber optic'. This cell is invisible if a second rear communications port or an Ethernet card is fitted, as they are mutually exclusive and occupy the same physical location.

7. The following cell which may be displayed, is not currently used but is available for future expansion

```
RP1 InactivTimer
```

8. The next cell down can be used for monitor or command blocking:

```
RP1 CS103Blocking
```

There are three settings associated with this cell; these are:

• Disabled	No blocking selected.
• Monitor Blocking	When the monitor blocking DDB Signal is active high, either by energizing an opto input or control input, reading of the status information and disturbance records is not permitted. When in this mode the relay returns a "Termination of general interrogation" message to the master station.
• Command Blocking	When the command blocking DDB signal is active high, either by energizing an opto input or control input, all remote commands will be ignored (i.e. CB Trip/Close, change setting group etc.). When in this mode the relay returns a "negative acknowledgement of command" message to the master station.

2.2.5 Configuring the DNP3.0 Rear Port, RP1 and Optional DNP3.0 over Ethernet

The DNP3.0 protocol is defined and administered by the DNP User Group. Information about the user group, DNP3.0 in general and protocol specifications can be found on their website: www.dnp.org

The DNP3.0 implementation in the relay can be presented on an EIA(RS)485 physical layer, and/or on an Ethernet connection according to the options selected.

The settings applicable to the EIA(RS)485 implementation are described in section 2.2.5.1. The settings applicable to the Ethernet implementation are described in section 2.2.5.2.

The relay operates as a DNP3.0 slave and supports subset Level 2 of the protocol plus some of the features from Level 3.

2.2.5.1 Configuring the DNP3.0 Rear Port, RP1

DNP3.0 communication can be achieved via a twisted pair EIA(RS)485 connection to the rear port and can be used over a distance of 1000 m with up to 32 slave devices.

1. To use the rear port with DNP3.0 communication, configure the relay's communication settings using the keypad and LCD user interface.
2. In the relay menu, select the **Configuration** column, then check that the **Comms. settings** cell is set to **Visible**.
3. Four settings apply to the rear port using IEC 60870-5-103 that are described below.
4. Move down the 'COMMUNICATIONS' column from the column heading to the first cell that indicates the communications protocol:

```
RP1 Protocol
DNP3.0
```

5. The next cell sets the device address on the DNP3.0 network:

```
RP1 Address
232
```

Up to 32 devices can be connected to one DNP3.0 spur, and therefore it is necessary for each device to have a unique address so that messages from the master control station are accepted by only one device. DNP3.0 uses a decimal number between 1 and 65519 for the device address. It is important that no two devices have the same address. The address is then used by the DNP3.0 master station to communicate with the relay.

6. The next cell sets the baud rate to be used:

```
RP1 Baud Rate
9600 bits/s
```

DNP3.0 communication is asynchronous. Six baud rates are supported by the relay '1200bits/s', '2400bits/s', '4800bits/s', '9600bits/s', '19200bits/s' and '38400bits/s'. It is important that whatever baud rate is selected on the relay is the same as that set on the DNP3.0 master station.

7. The next cell controls the parity format used in the data frames:

```
RP1 Parity
None
```

The parity can be set to be one of **None**, **Odd** or **Even.** It is important that whatever parity format is selected on the relay is the same as that set on the DNP3.0 master station.

An optional fiber optic card is available in the relay to allow optical connection to the IEC 60870-5-103 communication to be made over an optical connection. When fitted, it converts between EIA(RS)485 signals and fiber optic signals and the following cell is visible in the menu column.

8. The next cell down the column controls the physical media used for the communication.

```
RP1 Physical link
Copper
```

The default setting is to select the electrical (copper) connection. If the optional fiber optic interface is fitted to the relay, then this setting can be changed to **Fiber optic**. This cell is invisible if a second rear communications port or an Ethernet card is fitted, as they are mutually exclusive and occupy the same physical location.

9. The next cell down the column sets the time synchronization request from the master by the relay:

```
RP1 Time Sync.
Enabled
```

The time synchronization can be set to either enabled or disabled. If enabled it allows the DNP3.0 master to synchronize the time.

10. Analogue values can be set to be reported in terms of primary, secondary or normalized (with respect to the CT/VT ratio setting) values:

```
Meas Scaling
Primary
```

11. A message gap setting is provided:

```
Message Gap
0
```

This allows a gap between message frames to be set to enable compatibility with different master stations.

The setting for enabling/disabling DNP3.0 time synchronization is described above. When DNP3.0 time sync is enabled, the required rate of synchronization, known as the “need time”, needs to be set.

12. A setting allows different “need time” to be set with setting range from 1 - 30 minutes, step of 1 minute and default at 10 minutes:

```
DNP Need Time
10mins
```

The transmitted application fragment size can be set to ensure that a Master Station cannot be held too long before a complete reply is received and allow it to move on to next IED in a token ring polling setup.

13. The maximum overall response message length can be configured:

```
DNP App Fragment
2048
```

A single fragment size is 249. Depending on circumstances, a user may set the fragment size as a multiple of 249 in order to optimize segment packing efficiency in fragments. However it can also be useful to allow "odd" sizes for users to choose under specific circumstances, such as if sending data inside SMS frames, through packet radios, etc. In such cases it can be useful to select the fragment size such that each packet occupies a single "transmission media frame".

In some cases, communication to the outstation is made over slow, packet-switched networks which can add seconds to the communication latency.

14. A setting is provided to allow the application layer timeout to be set:

```
DNP App Timeout
2s
```

15. Select Before Operate (SBO) timeouts can be set.
If the DNP3.0 “Select a trip command” causes the relay’s internal logic to block automatic tripping, then a corruption of the DNP3.0 “Operate” message could delay the trip. The delay of tripping can be set:

```
DNP SBO Timeout
10s
```

16. The DNP link timeout can be set:

```
DNP Link Timeout
10s
```

2.2.5.2 Configuring the (optional) DNP3.0 over Ethernet port

When DNP3.0 is provided over Ethernet, settings similar to those described above for the EIA(RS)485 connection are provided for the following:

- Time Sync.
- Meas. Scaling
- DNP Need Time
- DNP App Fragment
- DNP App Timeout
- DNP SBO Timeout

For these settings, please refer to the descriptions provided in the previous section.

As well as these, other settings as described below are provided to complete the configuration of the DNP3.0 over Ethernet configuration.

1. Add a timeout setting to define how long the device will wait before an inactive tunnel connection to the master station is reset:

```
NIC Tunl Timeout
5mins
```

2. Use the NIC Link Report setting to configure how a failed/disconnected network link (copper or fiber) is reported. Options are to report an alarm, an event, or nothing:

```
NIC Link Report
Alarm
```

3. Set the duration of time elapsed, after a failed network link is detected and before communication by the alternative media interface is attempted:

```
NIC Link Timeout
60s
```

4. Set the rate at which the SNTP server is polled:

```
SNTP Poll Rate
64s
```

3 COURIER INTERFACE

3.1 Courier Protocol

Courier is a Schneider Electric communication protocol. The concept of the protocol is that a standard set of commands is used to access a database of settings and data in the relay. This allows a generic master to be able to communicate with different slave devices. The application-specific aspects are contained in the database rather than the commands used to interrogate it, so the master station does not need to be preconfigured.

The same protocol can be used through two physical links K-Bus or EIA(RS)-232.

K-Bus is based on EIA(RS)-485 voltage levels with HDLC FM0 encoded synchronous signaling and its own frame format. The K-Bus twisted pair connection is unpolarized, whereas the EIA(RS)-485 and EIA(RS)-232 interfaces are polarized.

The EIA(RS)-232 interface uses the IEC60870-5 FT1.2 frame format.

The relay supports an IEC60870-5 FT1.2 connection on the front-port. This is intended for temporary local connection and is not suitable for permanent connection. This interface uses a fixed baud rate, 11-bit frame, and a fixed device address.

The rear interface is used to provide a permanent connection for K-Bus and allows multi-drop connection. Although K-Bus is based on EIA(RS)-485 voltage levels, it is a synchronous HDLC protocol using FM0 encoding. It is not possible to use a standard EIA(RS)-232 to EIA(RS)-485 converter to convert IEC60870-5 FT1.2 frames to K-Bus. Also it is not possible to connect K-Bus to an EIA(RS)-485 computer port. A protocol converter, such as the KITZ101, should be used for this purpose.

For a detailed description of the Courier protocol, command-set and link description, see the following documentation:

R6509	K-Bus Interface Guide
R6510	IEC60870 Interface Guide
R6511	Courier Protocol
R6512	Courier User Guide

3.2 Front Courier Port

The front EIA(RS)-232 9 pin port supports the Courier protocol for one-to-one communication. The RS232 port complies with EIA(RS)-574; the 9-pin version of EIA(RS)-232, see www.tiaonline.org. This port is designed for use during installation and commissioning/maintenance and is not suitable for permanent connection. Since this interface is not used to link the relay to a substation communication system, some of the features of Courier are not implemented. These are as follows:

- Automatic extraction of Event Records:
  - Courier Status byte does not support the Event flag.
  - Send Event/Accept Event commands are not implemented.
- Automatic extraction of Disturbance records:
  - Courier Status byte does not support the Disturbance flag.
- Busy Response Layer:
  - Courier Status byte does not support the Busy flag, the only response to a request is the final data.

- Fixed Address:
    - The address of the front Courier port is always 1; the Change Device address command is not supported.
- Fixed Baud Rate:
    - 19200 bps.
    - Although automatic extraction of event and disturbance records is not supported, it is possible to manually access this data through the front port.

3.3 Supported Command Set

The following Courier commands are supported by the relay:

Protocol Layer

Reset Remote Link
Poll Status
Poll Buffer*

Low Level Commands

Send Event*
Accept Event*
Send Block
Store Block Identifier
Store Block Footer

Menu Browsing

Get Column Headings
Get Column Text
Get Column Values
Get Strings
Get Text
Get Value
Get Column Setting Limits

Setting Changes

Enter Setting Mode
Preload Setting
Abort Setting
Execute Setting
Reset Menu Cell
Set Value

Control Commands

Select Setting Group
Change Device Address*
Set Real Time

Note *Commands indicated with a * are not supported via the front Courier port.*

3.4 Relay Courier Database

The Courier database is a two dimensional structure with each cell in the database being referenced by a row and column address. Both the column and the row can take a range from 0 to 255. Addresses in the database are specified as hexadecimal values; e.g. 0A02 is column 0A (10 decimal) row 02. Associated settings/data will be part of the same column, row zero of the column contains a text string to identify the contents of the column, i.e. a column heading.

The menu database manual contains the complete database definition for the relay. For each cell location the following information is stated:

- Cell text
- Cell datatype
- Cell value
- Whether the cell is settable, if so
- Minimum value
- Maximum value
- Step size
- Password level required to allow setting changes
- String information (for Indexed String or Binary flag cells)

3.5 Setting Changes

(See R6512, Courier User Guide - Chapter 9)

Courier provides two mechanisms for making setting changes, both of these are supported by the relay. Either method can be used for editing any of the settings in the relay database.

3.5.1 Method 1

This uses a combination of three commands to perform a settings change:

Enter Setting Mode	Checks that the cell is settable and returns the limits.
Preload Setting	Places a new value to the cell. This value is echoed to ensure that setting corruption has not taken place. The validity of the setting is not checked by this action.
Execute Setting	Confirms the setting change. If the change is valid, a positive response is returned. If the setting change fails, an error response is returned.
Abort Setting	This command can be used to abandon the setting change.

This is the most secure method. It is ideally suited to on-line editors because the setting limits are taken from the relay before the setting change is made. However, this method can be slow if many settings are being changed because three commands are required for each change.

3.5.2 Method 2

The **Set Value** command can be used to directly change a setting, the response to this command is either a positive confirm or an error code to indicate the nature of a failure. This command can be used to implement a setting more rapidly than the previous method, however the limits are not extracted from the relay. This method is most suitable for off-line setting editors such as MiCOM S1 Studio, or for issuing preconfigured (SCADA) control commands.

3.5.3 Relay Settings

There are three categories of settings within the relay database:

- Control and support
- Disturbance recorder
- Protection settings group

Setting changes made to the control and support settings are implemented immediately and stored in non-volatile memory. Changes made to either the disturbance recorder settings or the protection settings groups are stored in a ‘scratchpad’ memory and are not immediately implemented by the relay.

To action setting changes stored in the scratchpad the save changes cell in the configuration column must be written to. This allows the changes to either be confirmed and stored in non-volatile memory, or the setting changes to be aborted.

3.5.4 Setting Transfer Mode

If it is necessary to transfer all of the relay settings to or from the relay a cell within the communication system data column can be used. This cell (location BF03) when set to 1 makes all of the relay settings visible. Any setting changes made, with the relay set in this mode, are stored in scratchpad memory (including control and support settings). When the value of BF03 is set back to 0 any setting changes are verified and stored in non-volatile memory.

3.6 Event Extraction

Events can be extracted either automatically (rear port only) or manually (either Courier port). For automatic extraction all events are extracted in sequential order using the standard Courier event mechanism, this includes fault/maintenance data if appropriate. The manual approach allows the user to select events, faults, or maintenance data at random from the stored records.

3.6.1 Automatic Event Extraction

(See Chapter 7 Courier User Guide, publication R6512)

This method is intended for continuous extraction of event and fault information as it is produced. It is only supported via the rear Courier port.

When new event information is created the event bit is set within the status byte, this indicates to the master device that event information is available. The oldest, unextracted event can be extracted from the relay using the send event command. The relay will respond with the event data, which will be either a Courier Type 0 or Type 3 event. The Type 3 event is used for fault records and maintenance records.

Once an event has been extracted from the relay, the accept event can be used to confirm that the event has been successfully extracted. If all events have been extracted then the event bit will reset, if there are more events still to be extracted the next event can be accessed using the **Send Event** command as before.

3.6.2 Event Types

Events will be created by the relay under these circumstances:

- Change of state of output contact
- Change of state of opto input
- Protection element operation
- Alarm condition
- Setting change
- Password entered/timed-out
- Fault record (Type 3 Courier Event)
- Maintenance record (Type 3 Courier Event)

3.6.3 Event Format

The send event command results in these fields being returned by the relay:

- Cell reference
- Timestamp
- Cell text
- Cell value

The Relay Menu Database contains a table of the events created by the relay and indicates how the contents of the above fields are interpreted. Fault records and maintenance records will return a Courier Type 3 event, which contains the above fields together with two additional fields:

- Event extraction column

- Event number

These events contain additional information that is extracted from the relay using the referenced extraction column. Row 01 of the extraction column contains a setting that allows the fault/maintenance record to be selected. This setting should be set to the event number value returned within the record; the extended data can be extracted from the relay by uploading the text and data from the column.

3.6.4 Manual Event Record Extraction

Column 01 of the database can be used for manual viewing of event, fault, and maintenance records. The contents of this column will depend on the nature of the record selected. It is possible to select events by event number and to directly select a fault record or maintenance record by number.

Event Record Selection (Row 01):

> This cell can be set to a value between 0 to 249 to select which of the 512 stored events is selected, 0 will select the most recent record; 249 the oldest stored record. For simple event records, (Type 0) cells 0102 to 0105 contain the event details. A single cell is used to represent each of the event fields. If the event selected is a fault or maintenance record (Type 3) then the remainder of the column will contain the additional information.

Fault Record Selection (Row 05):

> This cell can be used to directly select a fault record using a value between 0 and 4 to select one of up to five stored fault records. (0 will be the most recent fault and 4 will be the oldest). The column will then contain the details of the fault record selected.

Maintenance Record Selection (Row F0):

> This cell can be used to select a maintenance record using a value between 0 and 4 and operates in a similar way to the fault record selection.

Note *If this column is used to extract event information from the relay the number associated with a particular record will change when a new event or fault occurs.*

3.7 Disturbance Record Extraction

Select Record Number (Row 01):

> This cell can be used to select the record to be extracted. Record 0 will be the oldest unextracted record, already extracted older records will be assigned positive values, and negative values will be used for more recent records. To facilitate automatic extraction via the rear port the disturbance bit of the status byte is set by the relay whenever there are unextracted disturbance records.

Once a record has been selected, using the above cell, the time and date of the record can be read from cell 02. The disturbance record itself can be extracted using the block transfer mechanism from cell B00B.

As has been stated, the rear Courier port can be used to automatically extract disturbance records as they occur. This operates using the standard Courier mechanism defined in Chapter 8 of the Courier User Guide. The front Courier port does not support automatic extraction although disturbance record data can be extracted manually from this port.

3.8 Programmable Scheme Logic (PSL) Settings

The Programmable Scheme Logic (PSL) settings can be uploaded from and downloaded to the relay using the block transfer mechanism defined in Chapter 12 of the Courier User Guide.

The following cells are used to perform the extraction:

- B204 Domain/: Used to select either PSL settings (Upload or download) or PSL configuration data (Upload only)
- B208 Sub-Domain: Used to select the Protection Setting Group to be uploaded/downloaded.
- B20C Version: Used on a download to check the compatibility of the file to be downloaded with the relay.
- B21C Transfer Mode: Used to set-up the transfer process.
- B120 Data Transfer Cell: Used to perform upload/download.

The PSL settings can be uploaded and downloaded to and from the relay using this mechanism. If it is necessary to edit the settings MiCOM S1 Studio must be used as the data format is compressed. MiCOM S1 Studio also performs checks on the validity of the settings before they are downloaded to the relay.

4 IEC60870-5-103 INTERFACE

The IEC60870-5-103 interface is a master/slave interface with the relay as the slave device. The relay conforms to compatibility level 2; compatibility level 3 is not supported.

The following IEC60870-5-103 facilities are supported by this interface:

- Initialization (reset)
- Time synchronization
- Event record extraction
- General interrogation
- Cyclic measurements
- General commands
- Disturbance record extraction
- Private codes

4.1 Physical Connection and Link Layer

Two connection options are available for IEC60870-5-103, either the rear EIA(RS)485 port or an optional rear fiber optic port. Should the fiber optic port be fitted the selection of the active port can be made via the front panel menu or the front Courier port, however the selection will only be effective following the next relay power up.
For either of the two modes of connection it is possible to select both the relay address and baud rate using the front panel menu/front Courier. Following a change to either of these two settings a reset command is required to re-establish communications, see reset command description below.

4.2 Initialization

Whenever the relay has been powered up, or if the communication parameters have been changed a reset command is required to initialize the communications. The relay will respond to either of the two reset commands (Reset CU or Reset FCB), the difference being that the Reset CU will clear any unsent messages in the relay’s transmit buffer.
The relay will respond to the reset command with an identification message ASDU 5, the Cause Of Transmission COT of this response will be either Reset CU or Reset FCB depending on the nature of the reset command. The content of ASDU 5 is described in the IEC60870-5-103 section of the menu database.

In addition to the above identification message, if the relay has been powered up it will also produce a power up event.

4.3 Time Synchronization

The relay time and date can be set using the time synchronization feature of the IEC60870-5-103 protocol. The relay will correct for the transmission delay as specified in IEC60870-5-103. If the time synchronization message is sent as a send/confirm message then the relay will respond with a confirm. Whether the time-synchronization message is sent as a send confirm or a broadcast (send/no reply) message, a time synchronization Class 1 event will be generated/produced.

If the relay clock is being synchronized using the IRIG-B input then it will not be possible to set the relay time using the IEC60870-5-103 interface. An attempt to set the time via the interface will cause the relay to create an event with the current date and time taken from the IRIG-B synchronized internal clock.

4.4 Spontaneous Events

Events are categorized using the following information:

- Function type
- Information number

The IEC60870-5-103 profile in the Relay Menu Database contains a complete listing of all events produced by the relay.

4.5 General Interrogation

The GI request can be used to read the status of the relay, the function numbers, and information numbers that will be returned during the GI cycle are indicated in the IEC60870-5-103 profile in the menu database.

4.6 Cyclic Measurements

The relay will produce measured values using ASDU 9 on a cyclical basis, this can be read from the relay using a Class 2 poll (note ADSU 3 is not used). The rate at which the relay produces new measured values can be controlled using the measurement period setting. This setting can be edited from the front panel menu/front Courier port and is active immediately following a change.

It should be noted that the measurands transmitted by the relay are sent as a proportion of 2.4 times the rated value of the analog value.

4.7 Commands

A list of the supported commands is contained in the menu database. The relay will respond to other commands with an ASDU 1, with a Cause Of Transmission (COT) indicating ‘negative acknowledgement’.

4.8 Test Mode

It is possible using either the front panel menu or the front Courier port to disable the relay output contacts to allow secondary injection testing to be performed. This is interpreted as ‘test mode’ by the IEC60870-5-103 standard. An event will be produced to indicate both entry to and exit from test mode. Spontaneous events and cyclic measured data transmitted whilst the relay is in test mode will have a COT of ‘test mode’.

4.9 Disturbance Records

For Software Releases prior to B0 (i.e. 57 and earlier):

The disturbance records are stored in uncompressed format and can be extracted using the standard mechanisms described in IEC60870-5-103.

Note	*IEC60870-5-103 only supports up to 8 records.*

For Software Release B0 - A & B:

The disturbance records are stored in uncompressed format and can be extracted using the standard mechanisms described in IEC60870-5-103. The Enhanced Disturbance Recorder software releases mean the relay can store a minimum of 15 records, each of 1.5 seconds duration.

Using relays with IEC 60870-5 CS 103 communication means they can store the same total record length. However, the IEC 60870-5 CS 103 communication protocol dictates that only 8 records (of 3 seconds duration) can be extracted via the rear port.

4.10 Blocking of Monitor Direction

The relay supports a facility to block messages in the monitor direction and also in the command direction. Messages can be blocked in the monitor and command directions using the menu commands, Communications - CS103 Blocking - Disabled/Monitor Blocking/ Command Blocking or DDB signals Monitor Blocked and Command Blocked.

5 DNP3.0 INTERFACE

5.1 DNP3.0 Protocol

The DNP3.0 protocol is defined and administered by the DNP Users Group. For information on the user group, DNP3.0 in general and the protocol specifications, see www.dnp.org

The descriptions given here are intended to accompany the device profile document that is included in the menu database. The DNP3.0 protocol is not described here, please refer to the documentation available from the user group. The device profile document specifies the full details of the DNP3.0 implementation for the relay. This is the standard format DNP3.0 document that specifies which objects, variations and qualifiers are supported. The device profile document also specifies what data is available from the relay via DNP3.0. The relay operates as a DNP3.0 slave and supports subset level 2 of the protocol, plus some of the features from level 3.

DNP3.0 communication uses the EIA(RS)-485 communication port at the rear of the relay. The data format is 1 start bit, 8 data bits, an optional parity bit and 1 stop bit. Parity is configurable (see menu settings below).

5.2 DNP3.0 Menu Setting

The following settings are in the DNP3.0 menu in the **Communications** column.

Setting	Range	Description
Remote Address	0 - 65534	DNP3.0 address of relay (decimal)
Baud Rate	1200, 2400, 4800, 9600, 19200, 38400	Selectable baud rate for DNP3.0 communication
Parity	None, Odd, Even	Parity setting
RP1 Physical Link	Copper or Fiber Optic	This cell defines whether an electrical EIA(RS)485 or fiber optic connection is being used for communication between the master station and relay. If **Fiber Optic** is selected, the optional fiber optic communications board is required.
Time Sync.	Enabled, Disabled	Enables or disables the relay requesting time sync. from the master using IIN bit 4 word 1
Meas Scaling	Primary, Secondary or Normalized	Setting to report analog values in terms of primary, secondary or normalized (with respect to the CT/VT ratio setting) values.
Message Gap	0 - 50 msec	Setting to allow the master station to have an interframe gap.
DNP Need Time	1 - 30 mins	The length of time waited before requesting another time sync from the master.
DNP App Fragment	1 - 2048 bytes	The maximum message length (application fragment size) transmitted by the relay.
DNP App Timeout	1 -120 s	The length of time waited after sending a message fragment and waiting for a confirmation from the master.
DNP SBO Timeout	1 - 10 s	The length of time waited after receiving a select command and waiting for an operate confirmation from the master.

Setting	Range	Description
DNP Link Timeout	0 - 120 s	The length of time the relay waits for a Data Link Confirm from the master. A value of 0 means data link support disabled and 1 to 120 seconds is the timeout setting.

Table 1 - DNP3.0 menu in the Communications column

If the DNP3.0 over Ethernet option is selected, further settings are presented, as shown in this table.

Setting	Range	Description
DNP Time Sync.	Disabled or Enabled	If set to Enabled the DNP3.0 master station can be used to synchronize the time on the relay. If set to Disabled, either the internal free running clock or the IRIG-B input are used.
Meas Scaling	Primary, Secondary or Normalized	Setting to report analog values in terms of primary, secondary or normalized values, with respect to the CT/VT ratio setting.
NIC Tunl Timeout	1 - 30 mins	Time waited before an inactive tunnel to a master station is reset.
NIC Link Report	Alarm, Event or None	Configures how a failed or unfitted network link (copper or fiber) is reported: Alarm - an alarm is raised for a failed link Event - an event is raised for a failed link None - nothing reported for a failed link
NIC Link Timeout	0.1 - 60 s	Time waited, after failed network link is detected, before communication by the alternative media interface is attempted.

Table 2 - DNP3.0 over Ethernet option settings

5.3 Object 1 Binary Inputs

Object 1, binary inputs, contains information describing the state of signals within the relay which mostly form part of the Digital Data Bus (DDB). In general these include the state of the output contacts and input optos, alarm signals and protection start and trip signals. The ‘DDB number’ column in the device profile document provides the DDB numbers for the DNP3.0 point data. These can be used to cross-reference to the DDB definition list that is also found in the Relay Menu Database. The binary input points can also be read as change events via object 2 and object 60 for class 1-3 event data.

5.4 Object 10 Binary Outputs

Object 10, binary outputs, contains commands that can be operated via DNP3.0. As such the points accept commands of type pulse on [null, trip, close] and latch on/off as detailed in the device profile in the Relay Menu Database and execute the command once for either command. The other fields are ignored (queue, clear, trip/close, in time and off time).

Many of the relay’s functions are configurable, so some of the object 10 commands described below may not be available. A read from object 10 this will result in the point being reported as off-line and an operate command to object 12 will generate an error response.

Examples of object 10 points that maybe reported as off-line are:

• Activate setting groups	Ensure setting groups are enabled
• CB trip/close	Ensure remote CB control is enabled

Reset NPS thermal	Ensure NPS thermal protection is enabled
Reset thermal O/L	Ensure thermal overload protection is enabled
Reset RTD flags	Ensure RTD Inputs is enabled
Control Inputs	Ensure control inputs are enabled

There is an additional image of the Control Inputs. Described as alias Control Inputs, they reflect the state of the Control Inputs, but with a dynamic nature.

- If the Control Input DDB signal is already SET, and a new DNP SET command is sent to the Control Input, the Control Input DDB signal goes momentarily to RESET and then back to SET
- If the Control Input DDB signal is already RESET, and a new DNP RESET command is sent to that Control Input, the Control Input DDB signal goes momentarily to SET and then back to RESET

Figure 6 shows the behavior when the Control Input is set to Pulsed or Latched.

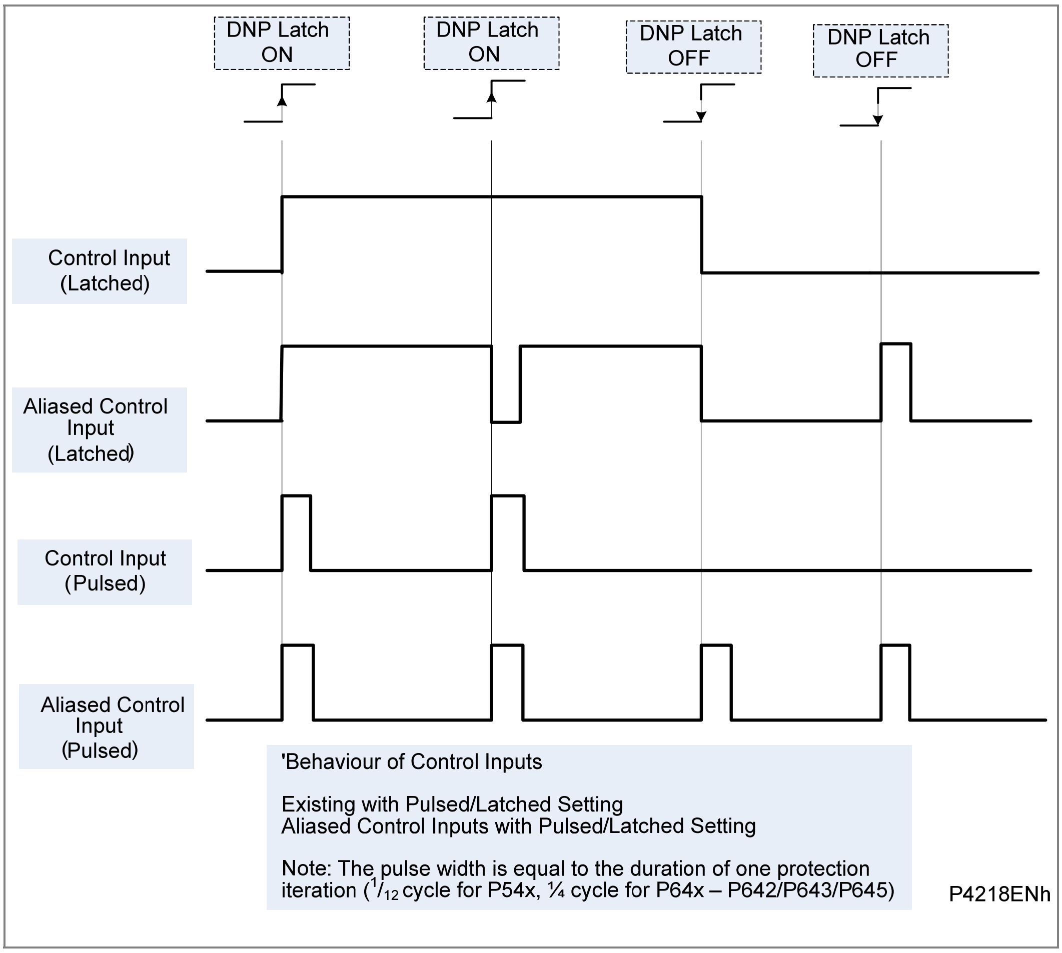

DNP Latch ON
DNP Latch ON
DNP Latch OFF
DNP Latch OFF
Control Input (Latched)
Aliased Control Input (Latched)
Control Input (Pulsed)
Aliased Control Input (Pulsed)
'Behaviour of Control Inputs
Existing with Pulsed/Latched Setting
Aliased Control Inputs with Pulsed/Latched Setting
Note: The pulse width is equal to the duration of one protection iteration ($^{1}/_{12}$ cycle for P54x, ¼ cycle for P64x – P642/P643/P645)
P4218ENh

Figure 6 - DNP3.0 behavior when control input is set to pulsed or latched

5.5 Object 20 Binary Counters

Object 20, binary counters, contains cumulative counters and measurements. The binary counters can be read as their present ‘running’ value from object 20, or as a ‘frozen’ value from object 21. The running counters of object 20 accept the read, freeze and clear functions. The freeze function takes the current value of the object 20 running counter and stores it in the corresponding object 21 frozen counter. The freeze and clear function resets the object 20 running counter to zero after freezing its value.

Binary counter and frozen counter change event values are available for reporting from object 22 and object 23 respectively. Counter change events (object 22) only report the most recent change, so the maximum number of events supported is the same as the total number of counters. Frozen counter change events (object 23) are generated when ever a freeze operation is performed and a change has occurred since the previous freeze command. The frozen counter event queues will store the points for up to two freeze operations.

5.6 Object 30 Analog Input

Object 30, analog inputs, contains information from the relay’s measurements columns in the menu. All object 30 points can be reported as 16 or 32 bit integer values with flag, 16 or 32 bit integer without flag as well as short floating-point values.

Analogue values can be reported to the master station as primary, secondary or normalized values (which takes into account the relay’s CT and VT ratios) and this is settable in the DNP3.0 Communications Column on the relay. Corresponding deadband settings can be displayed in terms of a primary, secondary or normalized value. Deadband point values can be reported and written too using Object 34 variations.

The deadband is the setting used to determine whether a change event should be generated for each point. The change events can be read via object 32 or object 60 and will be generated for any point whose value has changed by more than the deadband setting since the last time the data value was reported.

Any analog measurement that is unavailable at the time it is read will be reported as offline, e.g. the frequency when the current and voltage frequency is outside the tracking range of the relay or the thermal state when the thermal protection is disabled in the configuration column.

Note	*All object 30 points are reported as secondary values in DNP3.0 (with respect to CT and VT ratios).*

5.7 Object 40 Analog Output

The conversion to fixed-point format requires the use of a scaling factor, which is configurable for the various types of data within the relay e.g. current, voltage, phase angle etc. All Object 40 points report the integer scaling values and Object 41 is available to configure integer scaling quantities.

5.8 DNP3.0 Configuration using MiCOM S1

A PC support package for DNP3.0 is available as part of MiCOM S1 Studio to allow configuration of the relay’s DNP3.0 response. The PC is connected to the relay via a serial cable to the 9-pin front of the relay - see the Introduction chapter. The configuration data is uploaded from the relay to the PC in a block of compressed format data and downloaded to the relay in a similar manner after modification. The new DNP3.0 configuration takes effect in the relay after the download is complete. The default configuration can be restored at any time by choosing ‘All Settings’ from the ‘Restore Defaults’ cell in the menu ‘Configuration’ column.

In MiCOM S1 Studio, the DNP3.0 data is displayed on a three main tabbed screens, one screen each for the point configuration, integer scaling and default variation (data format). The point configuration also includes tabs for binary inputs, binary outputs, counters and analogue input configuration.

Please refer to the DNP3.0 Configurator Tool User guide (*S1V2DNP/EN HI/A11*) for details regarding the configuration of binary points, analogues and reporting format.

6 IEC 61850 ETHERNET INTERFACE

6.1 Introduction

IEC 61850 is the international standard for Ethernet-based communication in substations. It enables integration of all protection, control, measurement and monitoring functions within a substation, and additionally provides the means for interlocking and inter-tripping. It combines the convenience of Ethernet with the security which is essential in substations today.

The MiCOM protection relays can integrate with the PACiS substation control systems, to complete a full IEC 61850 solution for the substation. The majority of MiCOM Px3x and Px4x relay types can be supplied with Ethernet, in addition to traditional serial protocols. Relays which have already been delivered with UCA2.0 on Ethernet can be easily upgraded to IEC 61850.

6.2 What is IEC 61850?

IEC 61850 is an international standard, comprising 14 parts, which defines a communication architecture for substations.

The standard defines and offers much more than just a protocol. It provides:

- Standardized models for IEDs and other equipment within the substation
- Standardized communication services (the methods used to access and exchange data)
- Standardized formats for configuration files
- Peer-to-peer (e.g. relay to relay) communication

The standard includes mapping of data onto Ethernet. Using Ethernet in the substation offers many advantages, most significantly including:

- High-speed data rates (currently 100 Mbits/s, rather than 10’s of kbits/s or less used by most serial protocols)
- Multiple masters (called “clients”)
- Ethernet is an open standard in every-day use

Schneider Electric has been involved in the Working Groups which formed the standard, building on experience gained with UCA2.0, the predecessor of IEC 61850.

6.2.1 Interoperability

A major benefit of IEC 61850 is interoperability. IEC 61850 standardizes the data model of substation IEDs. This responds to the utilities’ desire of having easier integration for different vendors’ products, i.e. interoperability. It means that data is accessed in the same manner in different IEDs from either the same or different IED vendors, even though, for example, the protection algorithms of different vendors’ relay types remain different.

When a device is described as IEC 61850-compliant, this does not mean that it is interchangeable, but does mean that it is interoperable. You cannot simply replace one product with another, however the terminology is pre-defined and anyone with prior knowledge of IEC 61850 should be able very quickly integrate a new device without the need for mapping of all of the new data. IEC 61850 will inevitably bring improved substation communications and interoperability, at a lower cost to the end user.

6.2.2 Data Model

To ease understanding, the data model of any IEC 61850 IED can be viewed as a hierarchy of information. The categories and naming of this information is standardized in the IEC 61850 specification.

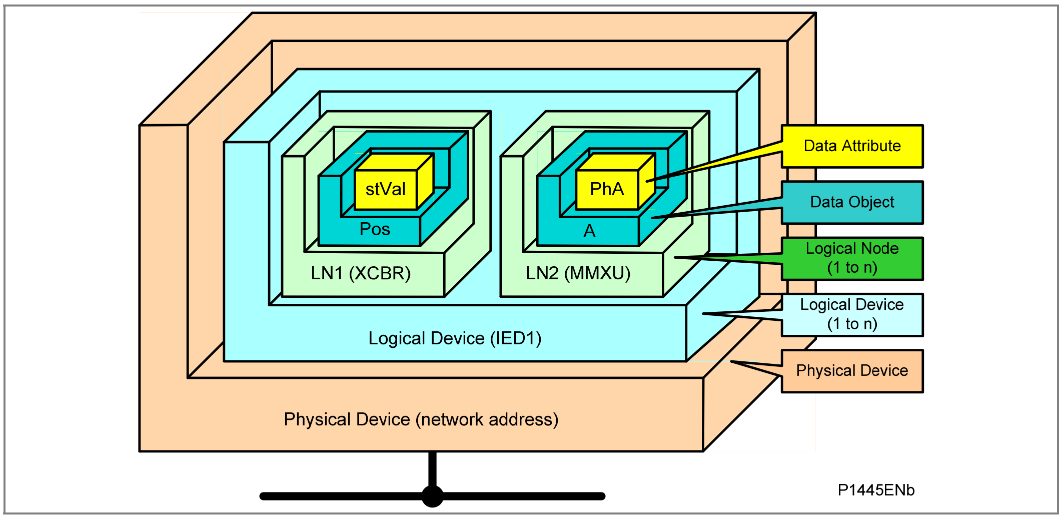


Figure 7 - Data model layers in IEC 61850

The levels of this hierarchy can be described as follows:

Physical Device	Identifies the actual IED within a system. Typically the device's name or IP address can be used (for example Feeder_1 or 10.0.0.2).
Logical Device	Identifies groups of related Logical Nodes within the Physical Device. For the MiCOM relays, 5 Logical Devices exist: Control, Measurements, Protection, Records, System.
Wrapper/Logical Node Instance	Identifies the major functional areas within the IEC 61850 data model. Either 3 or 6 characters are used as a prefix to define the functional group (wrapper) while the actual functionality is identified by a 4 character Logical Node name suffixed by an instance number. For example, XCBR1 (circuit breaker), MMXU1 (measurements), FrqPTOF2 (overfrequency protection, stage 2).
Data Object	This next layer is used to identify the type of data you will be presented with. For example, Pos (position) of Logical Node type XCBR.
Data Attribute	This is the actual data (measurement value, status, description, etc.). For example, stVal (status value) indicating actual position of circuit breaker for Data Object type Pos of Logical Node type XCBR.

6.3 IEC 61850 in MiCOM Relays

IEC 61850 is implemented in MiCOM relays by use of a separate Ethernet card. This card manages the majority of the IEC 61850 implementation and data transfer to avoid any impact on the performance of the protection.

In order to communicate with an IEC 61850 IED on Ethernet, it is necessary only to know its IP address. This can then be configured into either:

- An IEC 61850 "**client**" (or master), for example a PACiS computer (MiCOM C264) or HMI, or
- An "**MMS browser**", with which the full data model can be retrieved from the IED, without any prior knowledge

6.3.1 Capability

The IEC 61850 interface provides the following capabilities:

- Read access to measurements

  All measurands are presented using the measurement Logical Nodes, in the '**Measurements**' Logical Device. Reported measurement values are refreshed by the relay once per second, in line with the relay user interface.

- Generation of unbuffered reports on change of status/measurement

  Unbuffered reports, when enabled, report any change of state in statuses and/or measurements (according to deadband settings).

- Support for time synchronization over an Ethernet link

  Time synchronization is supported using SNTP (Simple Network Time Protocol); this protocol is used to synchronize the internal real time clock of the relays.

- GOOSE peer-to-peer communication

  GOOSE communications of statuses are included as part of the IEC 61850 implementation. Please see section 6.6 for more details.

- Disturbance record extraction

  Extraction of disturbance records, by file transfer, is supported by the MiCOM relays. The record is extracted as an ASCII format COMTRADE file.

- Controls

  The following control services are available:

  - Direct Control
  - Direct Control with enhanced security
  - Select Before Operate (SBO) with enhanced security
  - Controls are applied to open and close circuit breakers using XCBR.Pos and DDB signals 'Control Trip' and 'Control Close'.
  - System/LLN0. LLN0.LEDRs are used to reset any trip LED indications.

- Reports

  Reports only include data objects that have changed and not the complete dataset. The exceptions to this are a General Interrogation request and integrity reports.

- Buffered Reports

  Eight Buffered Report Control Blocks, (BRCB), are provided in SYSTEM/LLN0 in Logical Device 'System'.

  Buffered reports are configurable to use any configurable dataset located in the same Logical device as the BRCB (SYSTEM/LLN0).

- Unbuffered Reports

  Sixteen Unbuffered Report Control Blocks (URCB) are provided in SYSTEM/LLN0 in Logical Device 'System'.

  Unbuffered reports are configurable to use any configurable dataset located in the same Logical device as the URCB (SYSTEM/LLN0).

- Configurable Data Sets

  It is possible to create and configure datasets in any Logical Node using the IED Configurator. The maximum number of datasets will be specified in an IED's ICD file. An IED is capable of handling 100 datasets.

- Published GOOSE message

  Eight GOCBs are provided in SYSTEM/LLN0.

- Uniqueness of control

  The Uniqueness of control mechanism is implemented in the P64x to be consistent with the PACiS mechanism. This requires the relay to subscribe to the OrdRun signal from all devices in the system and be able to publish such a signal in a GOOSE message.

- Select Active Setting Group

  Functional protection groups can be enabled or disabled using private mod/beh attributes in the Protection/LLN0.OcpMod object. Setting groups are selectable using the Setting Group Control Block class, (SGCB). The Active Setting Group can be selected using the System/LLN0.SP.SGCB.ActSG data attribute in Logical Device 'System'.

- Quality for GOOSE

  It is possible to process the quality attributes of any Data Object in an incoming GOOSE message. Devices that do not support IEC61850 quality flags send quality attributes as all zeros.

- Address List

  An Address List document (to be titled ADL) is produced for each IED which shows the mapping between the IEC61850 data model and the internal data model of the IED. It includes a mapping in the reverse direction, which may be more useful. This document is separate from the PICS/MICS document.

- Originator of Control

  Originator of control mechanism is implemented for operate response message and in the data model on the ST of the related control object, consistent with the PACiS mechanism.

- Metering

  MMTR (metering) logical node is implemented in P14x. All metered values in the MMTR logical node are of type BCR. The actVal attribute of the BCR class is of type INT128, but this type is not supported by the SISCO MMSLite library. Instead, an INT64 value will be encoded for transmission.

  A SPC data object named MTTRs has been included in the MMTR logical node. This control will reset the demand measurements. A SPC data object named MTTRs is also included in the PTTR logical node. This control will reset the thermal measurements.

- Scaled Measurements

  The Unit definition, as per IEC specifies an SI unit and an optional multiplier for each measurement. This allows a magnitude of measurement to be specified e.g. mA, A, kA, MA.

  The multiplier will always be included in the Unit definition and will be configurable in SCL, but not settable at runtime. It will apply to the magnitude, rangeC.min & rangeC.max attributes. rangeC.min & rangeC.max will not be settable at runtime to be more consistent with Px30 and to reduce configuration problems regarding deadbands.

  Setting changes, such as changes to protection settings, are done using MiCOM S1 Studio. These changes can also be done using the relay's front port serial connection or the relay's Ethernet link, and is known as "tunneling".

6.3.2 IEC 61850 Configuration

One of the main objectives of IEC 61850 is to allow IEDs to be directly configured from a configuration file generated at system configuration time. At the system configuration level, the capabilities of the IED are determined from an IED capability description file (ICD) which is provided with the product. Using a collection of these ICD files from varying products, the entire protection of a substation can be designed, configured and tested (using simulation tools) before the product is even installed into the substation.

To aid in this process, the MiCOM S1 Support Software provides an IED Configurator tool which allows the pre-configured IEC 61850 configuration file (an SCD file or CID file) to be imported and transferred to the IED. Alongside this, the requirements of manual configuration are satisfied by allowing the manual creation of configuration files for MiCOM relays based on their original IED capability description (ICD file).

Other features include the extraction of configuration data for viewing and editing, and a sophisticated error checking sequence which ensures that the configuration data is valid for sending to the IED and that the IED will function within the context of the substation.

To aid the user, some configuration data is available in the '**IED CONFIGURATOR**' column of the relay user interface, allowing read-only access to basic configuration data.

6.3.2.1 Configuration Banks

To promote version management and minimize down-time during system upgrades and maintenance, the MiCOM relays have incorporated a mechanism consisting of multiple configuration banks. These configuration banks are categorized as:

- Active Configuration Bank
- Inactive Configuration Bank

Any new configuration sent to the relay is automatically stored into the inactive configuration bank, therefore not immediately affecting the current configuration. Both active and inactive configuration banks can be extracted at anytime.

When the upgrade or maintenance stage is complete, the IED Configurator tool can be used to transmit a command (to a single IED) authorizing the activation of the new configuration contained in the inactive configuration bank, by switching the active and inactive configuration banks. This technique ensures that the system down-time is minimized to the start-up time of the new configuration. The capability to switch the configuration banks is also available via the 'IED CONFIGURATOR' column.

For version management, data is available in the 'IED CONFIGURATOR' column in the relay user interface, displaying the SCL Name and Revision attributes of both configuration banks.

6.3.2.2 Network Connectivity

Note	*This section presumes a prior knowledge of IP addressing and related topics. Further details on this topic may be found on the Internet (search for IP Configuration) and in numerous relevant books.*

Configuration of the relay IP parameters (IP Address, Subnet Mask, Gateway) and SNTP time synchronization parameters (SNTP Server 1, SNTP Server 2) is performed by the IED Configurator tool, so if these parameters are not available via an SCL file, they must be configured manually.

If the assigned IP address is duplicated elsewhere on the same network, the remote communications will operate in an indeterminate way. However, the relay will check for a conflict on every IP configuration change and at power up. An alarm will be raised if an IP conflict is detected.

The relay can be configured to accept data from networks other than the local network by using the ‘Gateway’ setting.

6.4 Data Model of MiCOM Relays

The data model naming adopted in the Px30 and Px40 relays has been standardized for consistency. Hence the Logical Nodes are allocated to one of the five Logical Devices, as appropriate, and the wrapper names used to instantiate Logical Nodes are consistent between Px30 and Px40 relays.

The data model is described in the Model Implementation Conformance Statement (MICS) document, which is available separately. The MICS document provides lists of Logical Device definitions, Logical Node definitions, Common Data Class and Attribute definitions, Enumeration definitions, and MMS data type conversions. It generally follows the format used in Parts 7-3 and 7-4 of the IEC 61850 standard.

6.5 Communication Services of MiCOM Relays

The IEC 61850 communication services which are implemented in the Px30 and Px40 relays are described in the Protocol Implementation Conformance Statement (PICS) document, which is available separately. The PICS document provides the Abstract Communication Service Interface (ACSI) conformance statements as defined in Annex A of Part 7-2 of the IEC 61850 standard.

6.6 Peer-to-Peer (GSE) Communications

The implementation of IEC 61850 Generic Substation Event (GSE) sets the way for cheaper and faster inter-relay communications. The generic substation event model provides the possibility for a fast and reliable system-wide distribution of input and output data values. The generic substation event model is based on the concept of an autonomous decentralization, providing an efficient method allowing the simultaneous delivery of the same generic substation event information to more than one physical device through the use of multicast services.

The use of multicast messaging means that IEC 61850 GOOSE uses a publisher-subscriber system to transfer information around the network*. When a device detects a change in one of its monitored status points it publishes (i.e. sends) a new message. Any device that is interested in the information subscribes (i.e. listens) to the data it contains.

*Note** *Multicast messages cannot be routed across networks without specialized equipment.*

Each new message is re-transmitted at user-configurable intervals until the maximum interval is reached, in order to overcome possible corruption due to interference, and collisions. In practice, the parameters which control the message transmission cannot be calculated. Time must be allocated to the testing of GSE schemes before or during commissioning, in just the same way a hardwired scheme must be tested.

6.6.1 Scope

A maximum of 32 virtual inputs are available within the PSL which can be mapped directly to a published dataset in a GOOSE message (only 1 fixed dataset is supported). All published GOOSE signals are BOOLEAN values.

Each GOOSE signal contained in a subscribed GOOSE message can be mapped to any of the 32 virtual inputs within the PSL. The virtual inputs allow the mapping to internal logic functions for protection control, directly to output contacts or LEDs for monitoring.

The MiCOM relay can subscribe to all GOOSE messages but only the following data types can be decoded and mapped to a virtual input:

- BOOLEAN
- BSTR2
- INT16
- INT32
- INT8
- UINT16
- UINT32
- UINT8

6.6.2 IEC 61850 GOOSE Configuration

All GOOSE configuration is performed via the IED Configurator tool available within the MiCOM S1 Studio support software.

All GOOSE publishing configuration can be found under the ‘**GOOSE Publishing**’ tab in the configuration editor window. All GOOSE subscription configuration can be found under the ‘**GOOSE SUBSCRIBE**’ tab in the configuration editor window. You should make sure that the configuration is correct, to ensure efficient GOOSE scheme operation.

CONFIGURATION NOTE

Whilst the GOOSE messaging allows for fast and efficient passing of data between devices, the performance will be dependent on the configuration of the device; in particular the published dataset. The IED Configurator tool provides a warning bar that indicates the size of a defined dataset relative to the maximum size that can be published within a GOOSE message. As the size of the message approaches this maximum size, the performance may be impacted.

In addition, the Px40 device is designed to provide maximum performance through an optimized publishing mechanism. This optimized mechanism is enabled if the published GOOSE message is mapped using only the data attributes of the model rather than mapping a complete data object (see section 6.2.2). If data objects are mapped the GOOSE messaging will operate correctly; however without the benefit of the optimized mechanism.

Settings to enable GOOSE signaling and to apply Test Mode are available via the relay user interface.

6.7 Ethernet Functionality

Settings relating to a failed Ethernet link are available in the ‘COMMUNICATIONS’ column of the relay user interface.

6.7.1 Ethernet Disconnection

IEC 61850 ‘Associations’ are unique and made to the relay between the client (master) and server (IEC 61850 device). In the event that the Ethernet is disconnected, such associations are lost, and will need to be re-established by the client. The TCP_KEEPALIVE function is implemented in the relay to monitor each association, and terminate any which are no longer active.

6.7.2 Loss of Power

The relay allows the re-establishment of associations by the client without a negative impact on the relay’s operation after having its power removed. As the relay acts as a server in this process, the client must request the association. Uncommitted settings are cancelled when power is lost, and reports requested by connected clients are reset and must be re-enabled by the client when it next creates the new association to the relay.

SYMBOLS AND GLOSSARY

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Notes:

1 ACRONYMS AND ABBREVIATIONS

Term	Description
<	Less than: Used to indicate an “under” threshold, such as undercurrent (current dropout).
>	Greater than: Used to indicate an “over” threshold, such as overcurrent (current overload)
A	Ampere
AA	Application Association
AC / ac	Alternating Current
ACSI	Abstract Communication Service Interface
ACSR	Aluminum Conductor Steel Reinforced
ALF	Accuracy Limit Factor
AM	Amplitude Modulation
ANSI	American National Standards Institute
AR	Auto-Reclose.
ARIP	Auto-Reclose In Progress
ASCII	American Standard Code for Information Interchange
ATEX	ATEX is the Potentially Explosive Atmospheres directive 94/9/EC
AUX / Aux	Auxiliary
AWG	American Wire Gauge
BAR	Block Auto-Reclose signal.
BCD	Binary Coded Decimal
BCR	Binary Counter Reading
BDEW	Bundesverband der Energie- und Wasserwirtschaft | Startseite (i.e. German Association of Energy and Water Industries)
BMP	BitMaP – a file format for a computer graphic
BOP	Blocking Overreach Protection - a blocking aided-channel scheme.
BPDU	Bridge Protocol Data Unit
BRCB	Buffered Report Control Block
BRP	Beacon Redundancy Protocol
BU	Backup: Typically a back-up protection element
C264	MiCOM C264 is the latest generation of modular substation computers. In addition to the traditional input/output (I/O) management, MiCOM C264 acts as a powerful communication gateway, an advanced measurement center and a fast automation processor. As a remote terminal unit, bay controller or protocol converter, MiCOM C264 is the compact solution to countless applications installed in demanding electromagnetic conditions.
C/O	A ChangeOver contact having normally-closed and normally-open connections: Often called a “form C” contact.
CB	Circuit Breaker
CB Aux.	Circuit Breaker auxiliary contacts: Indication of the breaker open/closed status.
CBF	Circuit Breaker Failure protection
CDC	Common Data Class
CF	Control Function
Ch	Channel: usually a communications or signaling channel
Check Synch	Check Synchronizing function

Term	Description
CLIO	Current Loop Input Output: 0-1 mA/0-10 mA/0-20 mA/4-20 mA transducer inputs and outputs CLI = current loop input - 0-1 mA/0-10 mA/0-20 mA/4-20 mA transducer input CLO = current loop output - 0-1 mA/0-10 mA/0-20 mA/4-20 mA transducer output
CIP	Critical Infrastructure Protection standards
CLK / Clk	Clock
Cls	Close - generally used in the context of close functions in circuit breaker control.
CMV	Complex Measured Value
CNV	Current No Volts
CPNI	Centre for the Protection of National Infrastructure
CRC	Cyclic Redundancy Check
CRP	Cross-network Redundancy Protocol
CRV	Curve (file format for curve information)
CRx	Channel Receive: Typically used to indicate a teleprotection signal received.
CS	Check Synchronism.
CSV	Comma Separated Values (a file format for database information)
CT	Current Transformer
CTRL	Control - as used for the Control Inputs function
CTS	Current Transformer Supervision: To detect CT input failure.
CTx	Channel Transmit: Typically used to indicate a teleprotection signal send.
CUL	Canadian Underwriters Laboratory
CVT	Capacitor-coupled Voltage Transformer - equivalent to terminology CCVT.
DAU	Data Acquisition Unit
DC	Data Concentrator
DC / dc	Direct Current
DCC	An Omicron compatible format
DCE	Data Communication Equipment
DDB	Digital Data Bus within the programmable scheme logic: A logic point that has a zero or 1 status. DDB signals are mapped in logic to customize the relay’s operation.
DDR	Dynamic Disturbance Recorder
DEF	Directional Earth Fault protection: A directionalized ground fault aided scheme.
df/dt	Rate of Change of Frequency
df/dt>1	First stage of df/dt protection
DFT	Discrete Fourier Transform
DG	Distributed Generation
DHCP	Dynamic Host Configuration Protocol
DHM	Dual Homing Manager
DHP	Dual Homing Protocol
Diff	Differential protection.
DIN	Deutsches Institut für Normung (German standards body)
Dist	Distance protection.
DITA	Darwinian Information Typing Architecture
DLDB	Dead-Line Dead-Bus : In system synchronism check, indication that both the line and bus are de-energised.

Term	Description
DLLB	Dead-Line Live-Bus : In system synchronism check, indication that the line is de-energised whilst the bus is energised.
DLR	Dynamic Line Rating
DLY / Dly	Time Delay
DMT	Definite Minimum Time
DNP	Distributed Network Protocol
DPWS	Device Profile for Web Services
DSP	Digital Signal Processor
DST	Daylight Saving Time
DT	Definite Time: in the context of protection elements: An element which always responds with the same constant time delay on operation. Abbreviation of “Dead Time” in the context of auto-reclose:
DTD	Document Type Definition
DTOC	Definite Time Overcurrent
DTS	Date and Time Stamp
EF or E/F	Earth Fault (Directly equivalent to Ground Fault)
EIA	Electronic Industries Alliance
ELR	Environmental Lapse Rate
EMC	ElectroMagnetic Compatibility
ENA	Energy Networks Association
ER	Engineering Recommendation
ESD	Electrostatic Discharge
FAA	Ageing Acceleration Factor: Used by Loss of Life (LOL) element
FFail	A field failure (loss of excitation) element: Could be labeled 40 in ANSI terminology.
FFT	Fast Fourier Transform
FIR	Finite Impulse Response
FLC	Full load current: The nominal rated current for the circuit.
FLT / Flt	Fault - typically used to indicate faulted phase selection.
Fn or FN	Function
FPGA	Field Programmable Gate Array
FPS	Frames Per Second
FTP	File Transfer Protocol or Foil Twisted Pair
FWD, Fwd or Fwd.	Indicates an element responding to a flow in the “Forward” direction
Gen Diff	A generator differential element: Could be labeled 87G in ANSI terminology.
Gen-Xformer Diff	A generator-transformer differential element: Could be labeled 87GT in ANSI terminology.
GIF	Graphic Interchange Format – a file format for a computer graphic
GND / Gnd	Ground: used in distance settings to identify settings that relate to ground (earth) faults.
GOOSE	Generic Object Oriented Substation Event
GPS	Global Positioning System
GRP / Grp	Group. Typically an alternative setting group.

Term	Description
GSE	General Substation Event
GSSE	Generic Substation Status Event
GUESS	Generator Unintentional Energization at StandStill.
GUI	Graphical User Interface
HMI	Human Machine Interface
HSR	High-availability Seamless Ring
HTML	Hypertext Markup Language
I	Current
I/O	Input/Output
I/P	Input
IANA	Internet Assigned Numbers Authority
ICAO	International Civil Aviation Organization
ID	Identifier or Identification. Often a label used to track a software version installed.
IDMT	Inverse Definite Minimum Time. A characteristic whose trip time depends on the measured input (e.g. current) according to an inverse-time curve.
IEC	International Electro-technical Commission
IED	Intelligent Electronic Device - a term used to describe microprocessor-based controllers of power system equipment. Common types of IEDs include protective relaying devices, load tap changer controllers, circuit breaker controllers, capacitor bank switches, recloser controllers, voltage regulators, etc.
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IIR	Infinite Impulse Response
Inh	An Inhibit signal
Inst	An element with Instantaneous operation: i.e. having no deliberate time delay.
IP	Internet Protocol
IRIG	InterRange Instrumentation Group
ISA	International Standard Atmosphere
ISA	Instrumentation Systems and Automation Society
ISO	International Standards Organization
JPEF	Joint Photographic Experts Group – a file format for a computer graphic
L	Live
LAN	Local Area Network
LCD	Liquid Crystal Display: The front-panel text display on the relay.
LD	Level Detector: An element responding to a current or voltage below its set threshold.
LDOV	Level Detector for Overvoltage
LDUV	Level Detector for Undervoltage
LED	Light Emitting Diode: Red or green indicator on the front-panel.
LLDB	Live-Line Dead-Bus : In system synchronism check, indication that the line is energized whilst the bus is de-energized.
Ln	Natural logarithm
LN	Logical Node
LoL	A Loss of Load scheme, providing a fast distance trip without needing a signaling channel.
LPDU	Link Protocol Data Unit

Term	Description
LPHD	Logical Physical Device
MC	MultiCast
MCB	Miniature Circuit Breaker
MIB	Management Information Base
MICS	Model Implementation Conformance Statement
MIDOS	Modular Integrated DrawOut System
MMF	Magneto-Motive Force
MMS	Manufacturing Message Specification
MRP	Media Redundancy Protocol
MU	Merging Unit
MV	Measured Value
N	Neutral
N/A	Not Applicable
N/C	A Normally Closed or “break” contact: Often called a “form B” contact.
N/O	A Normally Open or “make” contact: Often called a “form A” contact.
NERC	North American Reliability Corporation
NIST	National Institute of Standards and Technology
NPS	Negative Phase Sequence
NVD	Neutral voltage displacement: Equivalent to residual overvoltage protection.
NXT	Abbreviation of “Next”: In connection with hotkey menu navigation.
O/C	Overcurrent
O/P	Output
OCB	Oil Circuit Breaker
OID	Object IDentifier
Opto	An Optically coupled logic input. Alternative terminology: binary input.
OSI	Open Systems Interconnection
PCB	Printed Circuit Board
PCT	Protective Conductor Terminal (Ground)
PDC	Phasor Data Concentrator
Ph	Phase - used in distance settings to identify settings that relate to phase-phase faults.
PICS	Protocol Implementation Conformance Statement
PMU	Phasor Measurement Unit
PNG	Portable Network Graphics – a file format for a computer graphic
Pol	Polarize - typically the polarizing voltage used in making directional decisions.
POR	A Permissive OverReaching transfer trip scheme (alternative terminology: POTT).
PRP	Parallel Redundancy Protocol
PSB	Power Swing Blocking, to detect power swing/out of step functions (ANSI 78).
PSL	Programmable Scheme Logic: The part of the relay’s logic configuration that can be modified by the user, using the graphical editor within MiCOM S1 Studio software.
PSlip	A Pole slip (out of step - OOS) element: could be labeled 78 in ANSI terminology.
PT	Power Transformer
PTP	Precision Time Protocol

Term	Description
PUR	A Permissive UnderReaching transfer trip scheme (alternative terminology: PUTT).
Q	Quantity defined as per unit value
R	Resistance
R&TTE	Radio and Telecommunications Terminal Equipment
RBAC	Role Based Access Control
RCA	Relay Characteristic Angle - The center of the directional characteristic.
REB	Redundant Ethernet Board
REF	Restricted Earth Fault
Rev.	Indicates an element responding to a flow in the “reverse” direction
RMS / rms	Root mean square. The equivalent a.c. current: Taking into account the fundamental, plus the equivalent heating effect of any harmonics.
RP	Rear Port: The communication ports on the rear of the IED
RS232	A common serial communications standard defined by the EIA
RS485	A common serial communications standard defined by the EIA (multi-drop)
RST or Rst	Reset generally used in the context of reset functions in circuit breaker control.
RSTP	Rapid Spanning Tree Protocol
RTD	Resistance Temperature Device
RTU	Remote Terminal Unit
Rx	Receive: Typically used to indicate a communication transmit line/pin.
SBS	Straight Binary Second
SC	Synch-Check or system Synchronism Check.
SCADA	Supervisory Control and Data Acquisition
SCL	Substation Configuration Language
SCU	Substation Control Unit
SEF	Sensitive Earth Fault Protection
Sen	Sensitive
SHM	Self-Healing Manager
SHP	Self Healing Protocol
SIR	Source Impedance Ratio
SLA	Service Level Agreement
SMV	Sampled Measured Values
SNTP	Simple Network Time Protocol
SOA	Service Oriented Architecture
SOAP	Simple Object Access Protocol
SOC	Second of Century
SOTF	Switch on to Fault protection. Modified protection on manual closure of the circuit breaker.
SP	Single pole.
SPAR	Single pole auto-reclose.
SPC	Single Point Controllable
SPDT	Single Pole Dead Time. The dead time used in single pole auto-reclose cycles.
SPS	Single Point Status
SQRT	Square Root
SSL	Source Impedance Ratio

Term	Description
STP	Shielded Twisted Pair or Spanning Tree Protocol
SV	Sampled Values
SVC	Sampled Value Model
SVM	Sampled Value Model
TAF	Turbine Abnormal Frequency
TCP	Transmission Control Protocol
TCS	Second of Century
TCS	Trip Circuit Supervision
TD	Time Dial. The time dial multiplier setting: Applied to inverse-time curves (ANSI/IEEE).
TE	Unit for case measurements: One inch = 5TE units
THD	Total Harmonic Distortion
TICS	Technical Issues Conformance Statement
TIFF	Tagged Image File Format – a file format for a computer graphic
TLS	Transport Layer Security protocol
TMS	Time Multiplier Setting: Applied to inverse-time curves (IEC)
TOC	Trip On Close (“line check”) protection. Offers SOTF and TOR functionality.
TOR	Trip On Reclose protection. Modified protection on autoreclosure of the circuit breaker.
TP	Two-Part
TUC	Timed UnderCurrent
TVE	Total Vector Error
Tx	Transmit
UDP	User Datagram Protocol
UL	Underwriters Laboratory
UPCT	User Programmable Curve Tool
UTC	Universal Time Coordinated
V	Voltage
VA	Phase A voltage: Sometimes L1, or red phase
VB	Phase B voltage: Sometimes L2, or yellow phase
VC	Phase C voltage: Sometimes L3, or blue phase
VCO	Voltage Controlled Overcurrent element
VDEP OC>	A voltage dependent overcurrent element: could be a voltage controlled or voltage restrained overcurrent element and could be labeled 51V in ANSI terminology.
VDR	Voltage Dependant Resistor
V/Hz	An overfluxing element, flux is proportional to voltage/frequency: could be labeled 24 in ANSI terminology.
Vk	IEC knee point voltage of a current transformer.
VT	Voltage Transformer
VTS	Voltage Transformer Supervision: To detect VT input failure.
WAN	Wide Area Network
Xformer	Transformer
XML	Extensible Markup Language

Term	Description
XSD	XML Schema Definition

Table 1 - Acronyms and abbreviations

2 COMPANY PROPRIETARY TERMS

Symbol	Description
Courier	Schneider Electric’s proprietary SCADA communications protocol
Metrosil	Brand of non-linear resistor produced by M&I Materials Ltd.
MiCOM	Schneider Electric’s brand of protection relays

Table 2 - Company-proprietary terms

3 ANSI TERMS

ANSI no.	Description
3PAR	Three pole auto-reclose.
3PDT	Three pole dead time. The dead time used in three pole auto-reclose cycles.
52a	A circuit breaker closed auxiliary contact: The contact is in the same state as the breaker primary contacts
52b	A circuit breaker open auxiliary contact: The contact is in the opposite state to the breaker primary contacts
64R	Rotor earth fault protection
64S	100% stator earth (ground) fault protection using a low frequency injection method.

Table 3 - ANSI abbreviations

ANSI no.	Function	Description
Current Protection Functions		
50/51	Phase overcurrent	Three-phase protection against overloads and phase-to-phase short-circuits.
50N/51N	Earth fault	Earth fault protection based on measured or calculated residual current values: • 50N/51N: residual current calculated or measured by 3 phase current sensors
50G/51G	Sensitive earth fault	Sensitive earth fault protection based on measured residual current values: • 50G/51G: residual current measured directly by a specific sensor such as a core balance CT
50BF	Breaker failure	If a breaker fails to be triggered by a tripping order, as detected by the non-extinction of the fault current, this backup protection sends a tripping order to the upstream or adjacent breakers.
46	Negative sequence / unbalance	Protection against phase unbalance, detected by the measurement of negative sequence current: • sensitive protection to detect 2-phase faults at the ends of long lines • protection of equipment against temperature build-up, caused by an unbalanced power supply, phase inversion or loss of phase, and against phase current unbalance
46BC	Broken conductor protection	Protection against phase imbalance, detected by measurement of I2/I1.
49RMS	Thermal overload	Protection against thermal damage caused by overloads on machines (transformers, motors or generators). The thermal capacity used is calculated according to a mathematical model which takes into account: • current RMS values • ambient temperature • negative sequence current, a cause of motor rotor temperature rise
Re-Closer		
79	Recloser	Automation device used to limit down time after tripping due to transient or semipermanent faults on overhead lines. The recloser orders automatic reclosing of the breaking device after the time delay required to restore the insulation has elapsed. Recloser operation is easy to adapt for different operating modes by parameter setting.
Directional Current Protection		
67N/67NC type 1 and 67	Directional phase overcurrent	Phase-to-phase short-circuit protection, with selective tripping according to fault current direction. It comprises a phase overcurrent function associated with direction detection, and picks up if the phase overcurrent function in the chosen direction (line or busbar) is activated for at least one of the three phases.

ANSI no.	Function	Description
67N/67NC	Directional earth fault	Earth fault protection, with selective tripping according to fault current direction. Three types of operation: • Type 1: the protection function uses the projection of the I0 vector • Type 2: the protection function uses the I0 vector magnitude with half-plane tripping zone • Type 3: the protection function uses the I0 vector magnitude with angular sector tripping zone
67N/67NC type 1	Directional current protection	Directional earth fault protection for impedant, isolated or compensated neutral systems, based on the projection of measured residual current.
67N/67NC type 2	Directional current protection	Directional overcurrent protection for impedance and solidly earthed systems, based on measured or calculated residual current. It comprises an earth fault function associated with direction detection, and picks up if the earth fault function in the chosen direction (line or busbar) is activated.
67N/67NC type 3	Directional current protection	Directional overcurrent protection for distribution networks in which the neutral earthing system varies according to the operating mode, based on measured residual current. It comprises an earth fault function associated with direction detection (angular sector tripping zone defined by 2 adjustable angles), and picks up if the earth fault function in the chosen direction (line or busbar) is activated.
Directional Power Protection Functions		

32P	Directional active overpower	Two-way protection based on calculated active power, for the following applications:
		• active overpower protection to detect overloads and allow load shedding
		• reverse active power protection:
		  • against generators running like motors when the generators consume active power
		  • against motors running like generators when the motors supply active power

32Q/40	Directional reactive overpower	Two-way protection based on calculated reactive power to detect field loss on synchronous machines: • reactive overpower protection for motors which consume more reactive power with field loss • reverse reactive overpower protection for generators which consume reactive power with field loss.
Machine Protection Functions		
37	Phase undercurrent	Protection of pumps against the consequences of a loss of priming by the detection of motor no-load operation. It is sensitive to a minimum of current in phase 1, remains stable during breaker tripping and may be inhibited by a logic input.

48/51LR/14	Locked rotor / excessive starting time	Protection of motors against overheating caused by:
		• excessive motor starting time due to overloads (e.g. conveyor) or insufficient supply voltage.
		The reacceleration of a motor that is not shut down, indicated by a logic input, may be considered as starting.
		• locked rotor due to motor load (e.g. crusher):
		  • in normal operation, after a normal start
		  • directly upon starting, before the detection of excessive starting time, with detection of locked rotor by a zero speed detector connected to a logic input, or by the underspeed function.

66	Starts per hour	Protection against motor overheating caused by:
		• too frequent starts: motor energizing is inhibited when the maximum allowable number of starts is reached, after counting of:
		  • starts per hour (or adjustable period)
		  • consecutive motor hot or cold starts (reacceleration of a motor that is not shut down, indicated by a logic input, may be counted as a start)
		• starts too close together in time: motor re-energizing after a shutdown is only allowed after an adjustable waiting time.

ANSI no.	Function	Description
50V/51V	Voltage-restrained overcurrent	Phase-to-phase short-circuit protection, for generators. The current tripping set point is voltage-adjusted in order to be sensitive to faults close to the generator which cause voltage drops and lowers the short-circuit current.
26/63	Thermostat/Buchholz	Protection of transformers against temperature rise and internal faults via logic inputs linked to devices integrated in the transformer.
38/49T	Temperature monitoring	Protection that detects abnormal temperature build-up by measuring the temperature inside equipment fitted with sensors: • transformer: protection of primary and secondary windings • motor and generator: protection of stator windings and bearings.
Voltage Protection Functions		
27D	Positive sequence undervoltage	Protection of motors against faulty operation due to insufficient or unbalanced network voltage, and detection of reverse rotation direction.
27R	Remanent undervoltage	Protection used to check that remanent voltage sustained by rotating machines has been cleared before allowing the busbar supplying the machines to be re-energized, to avoid electrical and mechanical transients.
27	Undervoltage	Protection of motors against voltage sags or detection of abnormally low network voltage to trigger automatic load shedding or source transfer. Works with phase-to-phase voltage.
59	Overvoltage	Detection of abnormally high network voltage or checking for sufficient voltage to enable source transfer. Works with phase-to-phase or phase-to-neutral voltage, each voltage being monitored separately.
59N	Neutral voltage displacement	Detection of insulation faults by measuring residual voltage in isolated neutral systems.
47	Negative sequence overvoltage	Protection against phase unbalance resulting from phase inversion, unbalanced supply or distant fault, detected by the measurement of negative sequence voltage.
Frequency Protection Functions		
81O	Overfrequency	Detection of abnormally high frequency compared to the rated frequency, to monitor power supply quality. Other organizations may use 81H instead of 81O.
81U	Underfrequency	Detection of abnormally low frequency compared to the rated frequency, to monitor power supply quality. The protection may be used for overall tripping or load shedding. Protection stability is ensured in the event of the loss of the main source and presence of remanent voltage by a restraint in the event of a continuous decrease of the frequency, which is activated by parameter setting. Other organizations may use 81L instead of 81U.
81R	Rate of change of frequency	Protection function used for fast disconnection of a generator or load shedding control. Based on the calculation of the frequency variation, it is insensitive to transient voltage disturbances and therefore more stable than a phase-shift protection function. **Disconnection** In installations with autonomous production means connected to a utility, the “rate of change of frequency” protection function is used to detect loss of the main system in view of opening the incoming circuit breaker to: • protect the generators from a reconnection without checking synchronization • avoid supplying loads outside the installation. **Load shedding** The “rate of change of frequency” protection function is used for load shedding in combination with the underfrequency protection to: • either accelerate shedding in the event of a large overload • or inhibit shedding following a sudden drop in frequency due to a problem that should not be solved by shedding.
Dynamic Line Rating (DLR) Protection Functions		

ANSI no.	Function	Description
49DLR	Dynamic line rating (DLR)	Protection of overhead lines based on calculation of rating or ampacity to dynamically take into account the effect of prevailing weather conditions as monitored by external sensors for: • Ambient Temperature • Wind Velocity • Wind Direction • Solar Radiation

Table 4 - ANSI descriptions

4 CONCATENATED TERMS

Term
Undercurrent
Overcurrent
Overfrequency
Underfrequency
Undervoltage
Overvoltage

Table 5 - Concatenated terms

5 UNITS FOR DIGITAL COMMUNICATIONS

Unit	Description
b	bit
B	Byte
kb	Kilobit(s)
kbps	Kilobits per second
kB	Kilobyte(s)
Mb	Megabit(s)
Mbps	Megabits per second
MB	Megabyte(s)
Gb	Gigabit(s)
Gbps	Gigabits per second
GB	Gigabyte(s)
Tb	Terabit(s)
Tbps	Terabits per second
TB	Terabyte(s)

Table 6 - Units for digital communications

6 AMERICAN VS BRITISH ENGLISH TERMINOLOGY

British English	American English
…ae…	…e…
…ence	…ense
…ise	…ize
…oe…	…e…
…ogue	…og
…our	…or
…ourite	…orite
…que	…ck
…re	…er
…yse	…yze
Aluminium	Aluminum
Centre	Center
Earth	Ground
Fibre	Fiber
Ground	Earth
Speciality	Specialty

Table 7 - American vs British English terminology

7 LOGIC SYMBOLS AND TERMS

Symbol	Description	Units
&	Logical “AND”: Used in logic diagrams to show an AND-gate function.	
Σ	“Sigma”: Used to indicate a summation, such as cumulative current interrupted.	
τ	“Tau”: Used to indicate a time constant, often associated with thermal characteristics.	
ω	System angular frequency	rad
<	Less than: Used to indicate an “under” threshold, such as undercurrent (current dropout).	
>	Greater than: Used to indicate an “over” threshold, such as overcurrent (current overload)	
o	A small circle on the input or output of a logic gate: Indicates a NOT (invert) function.	
1	Logical “OR”: Used in logic diagrams to show an OR-gate function.	
ABC	Clockwise phase rotation.	
ACB	Anti-Clockwise phase rotation.	
C	Capacitance	A
df/dt	Rate of Change of Frequency protection	Hz/s
df/dt>1	First stage of df/dt protection	Hz/s
F<	Underfrequency protection: Could be labeled 81-U in ANSI terminology.	Hz
F>	Overfrequency protection: Could be labeled 81-O in ANSI terminology.	Hz
F<1	First stage of under frequency protection: Could be labeled 81-U in ANSI terminology.	Hz
F>1	First stage of over frequency protection: Could be labeled 81-O in ANSI terminology.	Hz
f_{max}	Maximum required operating frequency	Hz
f_{min}	Minimum required operating frequency	Hz
f_{n}	Nominal operating frequency	Hz
I	Current	A
I∧	Current raised to a power: Such as when breaker statistics monitor the square of ruptured current squared (∧ power = 2).	An
I’f	Maximum internal secondary fault current (may also be expressed as a multiple of In)	A
I<	An undercurrent element: Responds to current dropout.	A
I>>	Current setting of short circuit element	In
I>	A phase overcurrent protection: Could be labeled 50/51 in ANSI terminology.	A
I>1	First stage of phase overcurrent protection: Could be labeled 51-1 in ANSI terminology.	A
I>2	Second stage of phase overcurrent protection: Could be labeled 51-2 in ANSI terminology.	A
I>3	Third stage of phase overcurrent protection: Could be labeled 51-3 in ANSI terminology.	A
I>4	Fourth stage of phase overcurrent protection: Could be labeled 51-4 in ANSI terminology.	A
I0	Earth fault current setting Zero sequence current: Equals one third of the measured neutral/residual current.	A
I1	Positive sequence current.	A
I2	Negative sequence current.	A
I2>	Negative sequence overcurrent protection (NPS element).	A
I2pol	Negative sequence polarizing current.	A
I2therm>	A negative sequence thermal element: Could be labeled 46T in ANSI terminology.	
IA	Phase A current: Might be phase L1, red phase.. or other, in customer terminology.	A
IB	Phase B current: Might be phase L2, yellow phase.. or other, in customer terminology.	A
IC	Phase C current: Might be phase L3, blue phase.. or other, in customer terminology.	A
Idiff	Current setting of biased differential element	A

Symbol	Description	Units
If	Maximum secondary through-fault current	A
If max	Maximum secondary fault current (same for all feeders)	A
If max int	Maximum secondary contribution from a feeder to an internal fault	A
If Z1	Maximum secondary phase fault current at Zone 1 reach point	A
Ife	Maximum secondary through fault earth current	A
IfeZ1	Maximum secondary earth fault current at Zone 1 reach point	A
Ifn	Maximum prospective secondary earth fault current or 31 x I> setting (whichever is lowest)	A
Ifp	Maximum prospective secondary phase fault current or 31 x I> setting (whichever is lowest)	A
I_m	Mutual current	A
IM64	InterMiCOM64.	
IMx	InterMiCOM64 bit (x=1 to 16)	
I_n	Current transformer nominal secondary current. The rated nominal current of the relay: Software selectable as 1 amp or 5 amp to match the line CT input.	A
IN	Neutral current, or residual current: This results from an internal summation of the three measured phase currents.	A
IN>	A neutral (residual) overcurrent element: Detects earth/ground faults.	A
IN>1	First stage of ground overcurrent protection: Could be labeled 51N-1 in ANSI terminology.	A
IN>2	Second stage of ground overcurrent protection: Could be labeled 51N-2 in ANSI terminology.	A
Inst	An element with “instantaneous” operation: i.e. having no deliberate time delay.	
I/O	Inputs and Outputs - used in connection with the number of optocoupled inputs and output contacts within the relay.	
I/P	Input	
Iref	Reference current of P63x calculated from the reference power and nominal voltage	A
IREF>	A Restricted Earth Fault overcurrent element: Detects earth (ground) faults. Could be labeled 64 in ANSI terminology.	A
IRm2	Second knee-point bias current threshold setting of P63x biased differential element	A
Is	Value of stabilizing current	A
IS1	Differential current pick-up setting of biased differential element	A
IS2	Bias current threshold setting of biased differential element	A
I_{SEF}>	Sensitive earth fault overcurrent element.	A
Isn	Rated secondary current (I secondary nominal)	A
Isp	Stage 2 and 3 setting	A
Ist	Motor start up current referred to CT secondary side	A
K	Dimensioning factor	
K_1	Lower bias slope setting of biased differential element	%
K_2	Higher bias slope setting of biased differential element	%
K_e	Dimensioning factor for earth fault	
km	Distance in kilometers	
K_{max}	Maximum dimensioning factor	
K_{rpa}	Dimensioning factor for reach point accuracy	
K_s	Dimensioning factor dependent upon through fault current	
K_{ssc}	Short circuit current coefficient or ALF	
K_t	Dimensioning factor dependent upon operating time	
kZm	The mutual compensation factor (mutual compensation of distance elements and fault locator for parallel line coupling effects).	

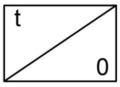
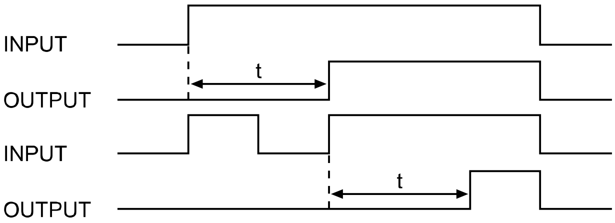
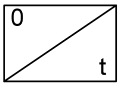
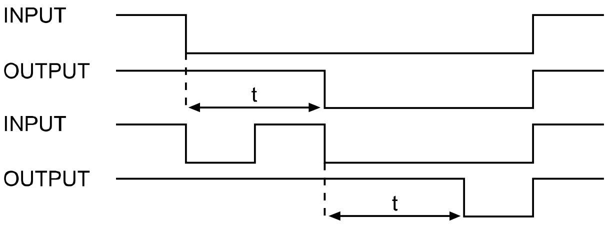
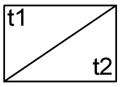
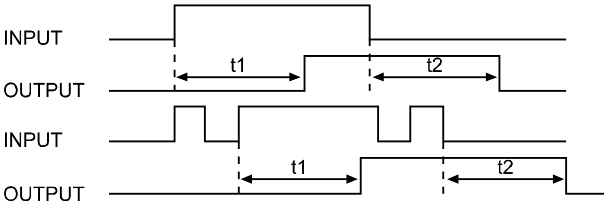
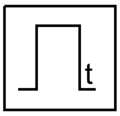
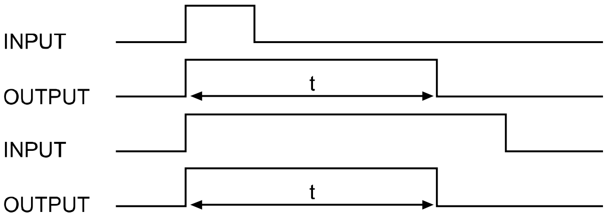
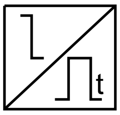
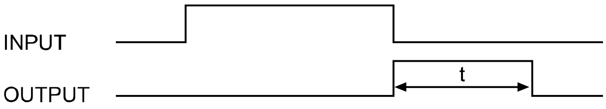
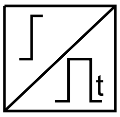
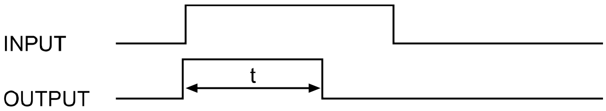
Symbol	Description	Units
kZN	The residual compensation factor: Ensuring correct reach for ground distance elements.	
L	Inductance	A
m1	Lower bias slope setting of P63x biased differential element	None
m2	Higher bias slope setting of P63x biased differential element	None
mi	Distance in miles.	
N	Indication of “Neutral” involvement in a fault: i.e. a ground (earth) fault.	
-P>	A reverse power (W) element: could be labeled 32R in ANSI terminology.	
P>	An overpower (W) element: could be labeled 32O in ANSI terminology.	
P<	A low forward power (W) element: could be labeled 32L in ANSI terminology.	
P1	Used in IEC terminology to identify the primary CT terminal polarity: Replace by a dot when using ANSI standards.	
P2	Used in IEC terminology to identify the primary CT terminal polarity: The non-dot terminal.	
P_n	Rotating plant rated single phase power	W
PN>	Wattmetric earth fault protection: Calculated using residual voltage and current quantities.	
Q<	A reactive under power (VAr) element	
R	Resistance (Ω)	Ω
R< or 64S R<	A 100% stator earth (ground) fault via low frequency injection under resistance element: could be labeled 64S in ANSI terminology.	
R Gnd.	A distance zone resistive reach setting: Used for ground (earth) faults.	
R Ph	A distance zone resistive reach setting used for Phase-Phase faults.	
Rct	Secondary winding resistance	Ω
Rl	Resistance of single lead from relay to current transformer	Ω
Rr	Resistance of any other protective relays sharing the current transformer	Ω
Rrn	Resistance of relay neutral current input	Ω
Rrp	Resistance of relay phase current input	Ω
Rs	Value of stabilizing resistor	Ω
Rx	Receive: typically used to indicate a communication receive line/pin.	
S<	An apparent under power (VA) element	
S1	Used in IEC terminology to identify the secondary CT terminal polarity: Replace by a dot when using ANSI standards.	
S2	Used in IEC terminology to identify the secondary CT terminal polarity: The non-dot terminal. Also used to signify negative sequence apparent power, S2 = V2 x I2.	
S2>	A negative sequence apparent power element, S2 = V2 x I2.	
t	A time delay.	
t’	Duration of first current flow during auto-reclose cycle	s
T1	Primary system time constant	s
TF	Through Fault monitoring	
tfr	Auto-reclose dead time	s
Thermal I>	A stator thermal overload element: could be labeled 49 in ANSI terminology.	
Thru/TF	Through Fault monitoring	
tIdiff	Current differential operating time	s
Ts	Secondary system time constant	s
Tx	Transmit: typically used to indicate a communication transmit line/pin.	
V	Voltage.	V
V<	An undervoltage element: could be labeled 27 in ANSI terminology	V

Symbol	Description	Units
V<1	First stage of undervoltage protection: Could be labeled 27-1 in ANSI terminology.	V
V<2	Second stage of undervoltage protection: Could be labeled 27-2 in ANSI terminology.	V
V>	An overvoltage element: could be labeled 59 in ANSI terminology	V
V>1	First stage of overvoltage protection: Could be labeled 59-1 in ANSI terminology.	V
V>2	Second stage of overvoltage protection: Could be labeled 59-2 in ANSI terminology.	V
V0	Zero sequence voltage: Equals one third of the measured neutral/residual voltage.	V
V1	Positive sequence voltage.	V
V2	Negative sequence voltage.	V
V2>	A negative phase sequence (NPS) overvoltage element: could be labeled 47 in ANSI terminology.	
$V2_{pol}$	Negative sequence polarizing voltage.	V
V_A	Phase A voltage: Might be phase L1, red phase.. or other, in customer terminology.	V
V_B	Phase B voltage: Might be phase L2, yellow phase.. or other, in customer terminology.	V
V_C	Phase C voltage: Might be phase L3, blue phase.. or other, in customer terminology.	V
Vf	Theoretical maximum voltage produced if CT saturation did not occur	V
Vin	Input voltage e.g. to an opto-input	V
V_k	Required CT knee-point voltage. IEC knee point voltage of a current transformer.	V
VN	Neutral voltage displacement, or residual voltage.	V
VN>	A residual (neutral) overvoltage element: could be labeled 59N in ANSI terminology.	V
V_n	Nominal voltage	V
Vn	The rated nominal voltage of the relay: To match the line VT input.	V
VN>1	First stage of residual (neutral) overvoltage protection.	V
VN>2	Second stage of residual (neutral) overvoltage protection.	V
VN3H>	A 100% stator earth (ground) fault 3rd harmonic residual (neutral) overvoltage element: could be labeled 59TN in ANSI terminology.	
VN3H<	A 100% stator earth (ground) fault 3rd harmonic residual (neutral) undervoltage element: could be labeled 27TN in ANSI terminology.	
Vres.	Neutral voltage displacement, or residual voltage.	V
Vs	Value of stabilizing voltage	V
V_x	An auxiliary supply voltage: Typically the substation battery voltage used to power the relay.	V
WI	Weak Infeed logic used in teleprotection schemes.	
X	Reactance	None
X/R	Primary system reactance/resistance ratio	None
Xe/Re	Primary system reactance/resistance ratio for earth loop	None
Xt	Transformer reactance (per unit)	p.u.
Y	Admittance	p.u.
Z	Impedance	p.u.
Z<	An under impedance element: could be labeled 21 in ANSI terminology.	
Z0	Zero sequence impedance.	
Z1	Positive sequence impedance.	
Z1	Zone 1 distance protection.	
Z1X	Reach-stepped Zone 1X, for zone extension schemes used with auto-reclosure.	
Z2	Negative sequence impedance.	
Z2	Zone 2 distance protection.	
ZP	Programmable distance zone that can be set forward or reverse looking.	

Symbol	Description	Units
Zs	Used to signify the source impedance behind the relay location.	
Φal	Accuracy limit flux	Wb
Ψr	Remanent flux	Wb
Ψs	Saturation flux	Wb

Table 8 - Logic Symbols and Terms

8 LOGIC TIMERS

Logic symbols	Explanation	Time chart
	Delay on pick-up timer, t	 INPUT t OUTPUT INPUT t OUTPUT
	Delay on drop-off timer, t	 INPUT OUTPUT t INPUT OUTPUT t
	Delay on pick-up/drop-off timer	 INPUT t1 t2 OUTPUT INPUT t1 t2 OUTPUT
	Pulse timer	 INPUT t OUTPUT INPUT t OUTPUT
	Pulse pick-up falling edge	 INPUT t OUTPUT
	Pulse pick-up raising edge	 INPUT t OUTPUT

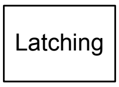
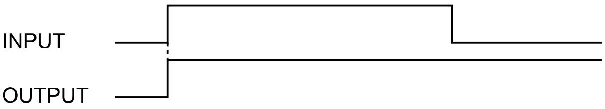
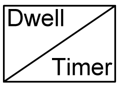
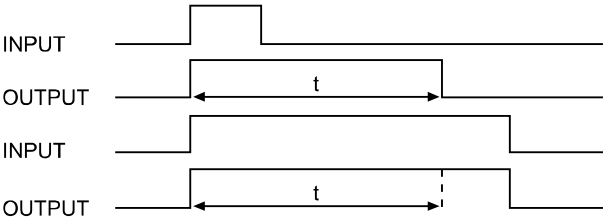
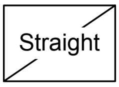
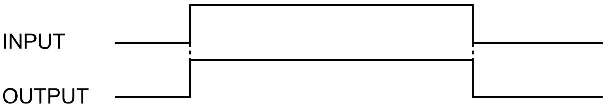
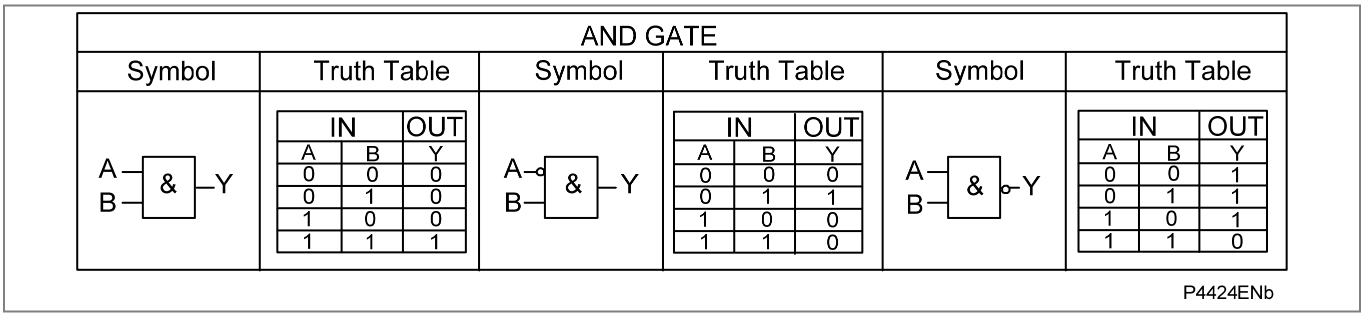
Logic symbols	Explanation	Time chart
	Latch	 INPUT OUTPUT
 Dwell Timer	Dwell timer	 INPUT OUTPUT t INPUT OUTPUT t
	Straight (non latching): Hold value until input reset signal	 INPUT OUTPUT

Table 9 - Logic Timers

9 LOGIC GATES

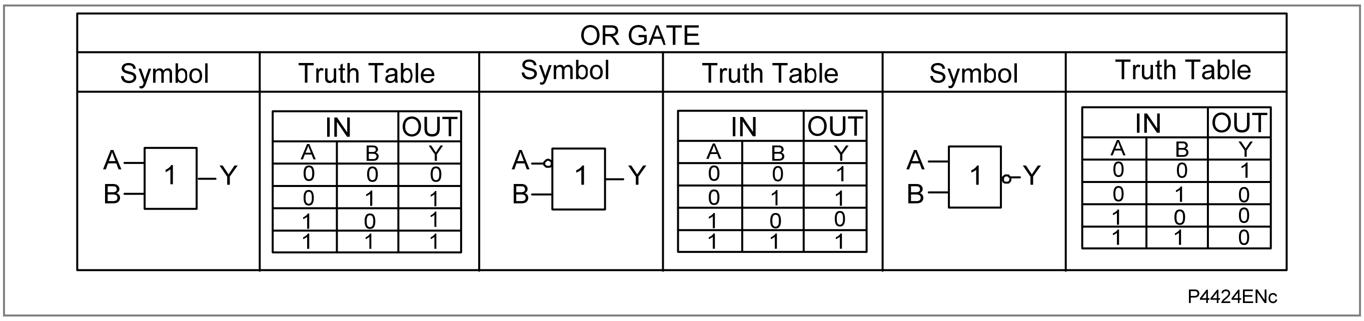

AND GATE
Symbol
Truth Table
A
B
&
Y
P4424ENb

IN		OUT
A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

IN		OUT
A	B	Y
0	0	0
0	1	1
1	0	0
1	1	0

IN		OUT
A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

Figure 1 - Logic Gates - AND Gate

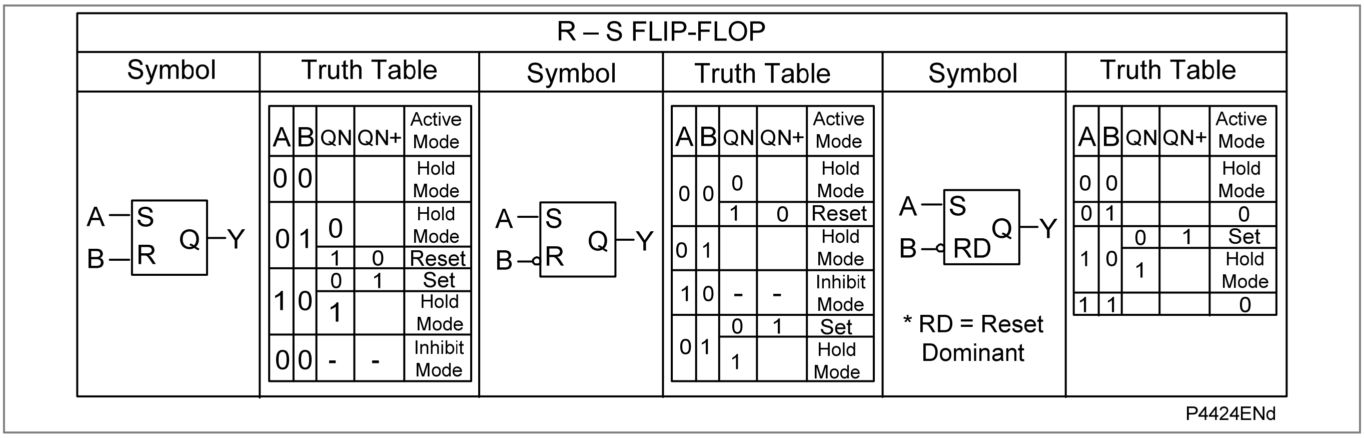

OR GATE
Symbol
Truth Table
A
B
1
Y
P4424ENc

IN		OUT
A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

IN		OUT
A	B	Y
0	0	1
0	1	1
1	0	0
1	1	1

IN		OUT
A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

Figure 2 - Logic Gates - OR Gate


R – S FLIP-FLOP
Symbol
Truth Table
A
B
S
R
RD
Q
Y
P4424ENd

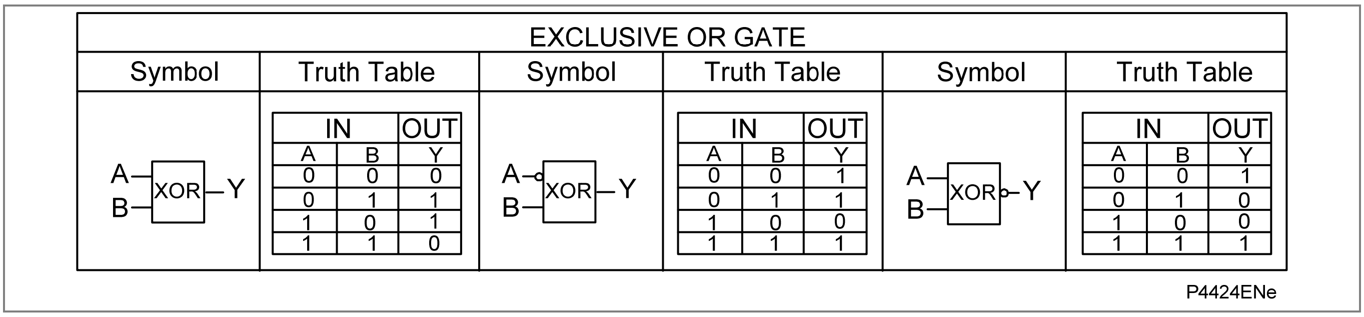
A	B	QN	QN+	Active Mode
0	0			Hold Mode
0	1	0		Hold Mode
		1	0	Reset
1	0	0	1	Set
		1		Hold Mode
0	0	-	-	Inhibit Mode

A	B	QN	QN+	Active Mode
0	0	0		Hold Mode
		1	0	Reset
0	1			Hold Mode
1	0	-	-	Inhibit Mode
0	1	0	1	Set
		1		Hold Mode

* RD = Reset Dominant

A	B	QN	QN+	Active Mode
0	0			Hold Mode
0	1			0
1	0	0	1	Set
		1		Hold Mode
1	1			0

Figure 3 - Logic Gates - R-S Flip-Flop Gate

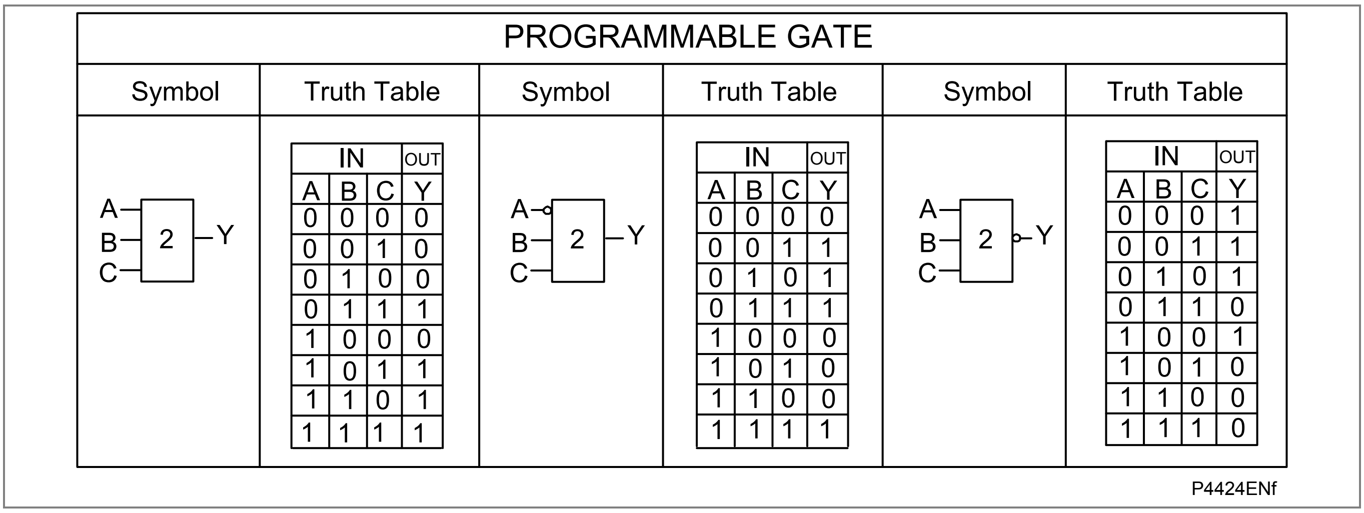

EXCLUSIVE OR GATE
Symbol
Truth Table
A
B
XOR
Y
P4424ENe

IN		OUT
A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

IN		OUT
A	B	Y
0	0	1
0	1	1
1	0	0
1	1	1

IN		OUT
A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1

Figure 4 - Logic Gates - Exclusive OR Gate

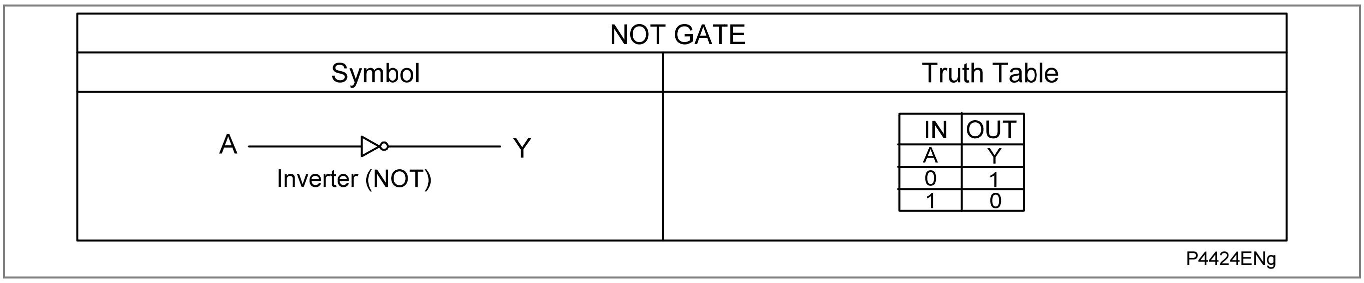

PROGRAMMABLE GATE
Symbol
Truth Table
Symbol
Truth Table
Symbol
Truth Table
A
B
C
2
Y
A
B
C
2
Y
A
B
C
2
Y
P4424ENf

IN			OUT
A	B	C	Y
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	1
1	1	1	1

IN			OUT
A	B	C	Y
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

IN			OUT
A	B	C	Y
0	0	0	1
0	0	1	1
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	0
1	1	1	0

Figure 5 - Logic Gates - Programmable Gate


NOT GATE
Symbol
Truth Table
A
Y
Inverter (NOT)
P4424ENg

IN	OUT
A	Y
0	1
1	0

Figure 6 - Logic Gates - NOT Gate

Notes:

INSTALLATION

CHAPTER 15

Date:	02/2013
Hardware Suffix:	K
Software Version:	55
Connection Diagrams:	10P44303 (SH 01 and 03) 10P44304 (SH 01 and 03) 10P44305 (SH 01 and 03) 10P44306 (SH 01 and 03) 10P44600 10P44601 (SH 1 to 2) 10P44602 (SH 1 to 2) 10P44603 (SH 1 to 2)

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1 RECEIPT, HANDLING, STORAGE AND UNPACKING

1.1 Receipt of Relays

Upon receipt, relays should be examined immediately to ensure no external damage has been sustained in transit. If damage has been sustained, a claim should be made to the transport contractor and Schneider Electric should be promptly notified.

Relays that are supplied unmounted and not intended for immediate installation should be returned to their protective polythene bags and delivery carton. Section 1.3 of P44y/EN IN gives more information about the storage of relays.

1.2 Handling of Electronic Equipment

Caution **Before carrying out any work on the equipment, the user should be familiar with the contents of the Safety Guide (SFTY/4L M/C11) or later issue, or the Safety and Technical Data sections of this Technical Manual and also the ratings on the equipment's rating label.**

A person's normal movements can easily generate electrostatic potentials of several thousand volts. Discharge of these voltages into semiconductor devices when handling electronic circuits can cause serious damage that, although not always immediately apparent, will reduce the reliability of the circuit. The relay's electronic circuits are protected from electrostatic discharge when housed in the case. Do not expose them to risk by removing the front panel or printed circuit boards unnecessarily.

Each printed circuit board incorporates the highest practicable protection for its semiconductor devices. However, if it becomes necessary to remove a printed circuit board, the following precautions should be taken to preserve the high reliability and long life for which the relay has been designed and manufactured.

Before removing a printed circuit board, ensure that you are at the same electrostatic potential as the equipment by touching the case.

Handle analog input modules by the front panel, frame or edges of the circuit boards. Printed circuit boards should only be handled by their edges. Avoid touching the electronic components, printed circuit tracks or connectors.

Do not pass the module to another person without first ensuring you are both at the same electrostatic potential. Shaking hands achieves equipotential.

Place the module on an anti-static surface, or on a conducting surface that is at the same potential as yourself.

If it is necessary to store or transport printed circuit boards removed from the case, place them individually in electrically conducting anti-static bags.

In the unlikely event that you are making measurements on the internal electronic circuitry of a relay in service, it is preferable that you are earthed to the case with a conductive wrist strap. Wrist straps should have a resistance to ground between 500kΩ to 10MΩ. If a wrist strap is not available you should maintain regular contact with the case to prevent a build-up of electrostatic potential. Instrumentation which may be used for making measurements should also be earthed to the case whenever possible.

More information on safe working procedures for all electronic equipment can be found in BS EN 100015: Part 1:1992. It is strongly recommended that detailed investigations on electronic circuitry or modification work should be carried out in a special handling area such as described in the British Standard document.

1.3 Storage

If relays are not to be installed immediately upon receipt, they should be stored in a place free from dust and moisture in their original cartons. Where de-humidifier bags have been included in the packing they should be retained.

To prevent battery drain during transportation and storage a battery isolation strip is fitted during manufacture. With the lower access cover open, presence of the battery isolation strip can be checked by a red tab protruding from the positive polarity side.

Care should be taken on subsequent unpacking that any dust, which has collected on the carton, does not fall inside. In locations of high humidity the carton and packing may become impregnated with moisture and the de-humidifier crystals will lose their efficiency.

Prior to installation, relays should be stored at a temperature of between –25˚C to +70˚C (-13˚F to +158˚F).

1.4 Unpacking

Care must be taken when unpacking and installing the relays so that none of the parts are damaged and additional components are not accidentally left in the packing or lost. Ensure that any User’s CDROM or technical documentation is NOT discarded - this should accompany the relay to its destination substation.

Note *With the lower access cover open, the red tab of the battery isolation strip will be seen protruding from the positive (+) side of the battery compartment. Do not remove this strip because it prevents battery drain during transportation and storage and will be removed as part of the commissioning tests.*

Relays must only be handled by skilled persons.

The site should be well lit to facilitate inspection, clean, dry and reasonably free from dust and excessive vibration.

2 RELAY MOUNTING

MiCOM relays are dispatched either individually or as part of a panel/rack assembly.

Individual relays are normally supplied with an outline diagram showing the dimensions for panel cutouts and hole centers. This information can also be found in the product publication.

Secondary front covers can also be supplied as an option item to prevent unauthorized changing of settings and alarm status. For MiCOM relays housed in 80TE cases, the relevant part number is GN0038 001.

The design of the relay is such that the fixing holes in the mounting flanges are only accessible when the access covers are open and hidden from sight when the covers are closed.

If a P991 or MMLG test block is to be included, it is recommended that, when viewed from the front, it be positioned on the right-hand side of the relay (or relays) with which it is associated. This minimizes the wiring between the relay and test block, and allows the correct test block to be easily identified during commissioning and maintenance tests.

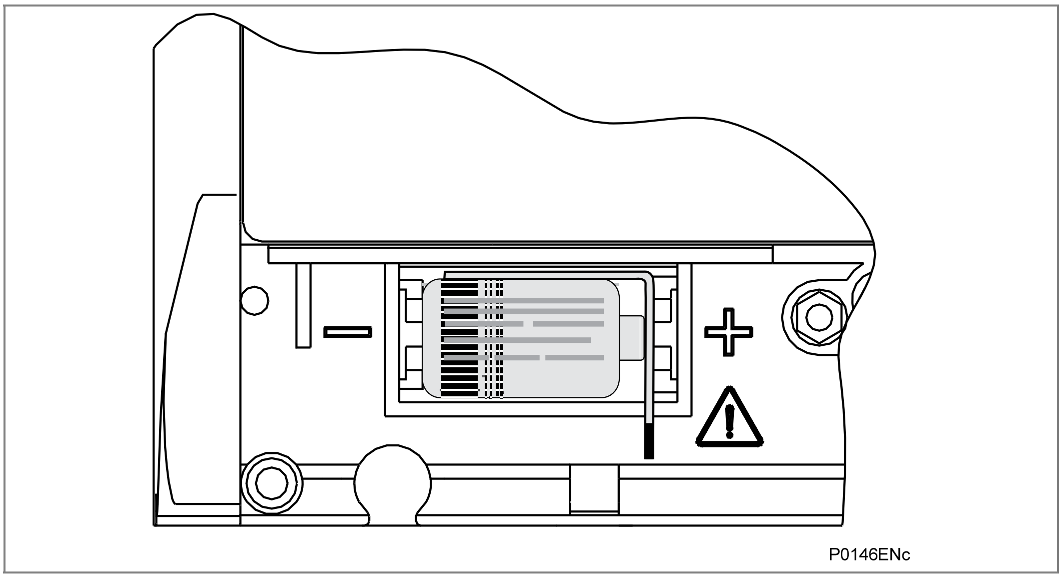


Figure 1 - Location of battery isolation strip

If it is necessary to test correct relay operation during the installation, the battery isolation strip can be removed but should be replaced if commissioning of the scheme is not imminent. The red tab of the isolation strip can be seen protruding from the positive side of the battery compartment when the lower access cover is open. To remove the isolation strip, pull the red tab whilst lightly pressing the battery to prevent it falling out of the compartment. When replacing the battery isolation strip, ensure that the strip is refitted as shown in Figure 1, i.e. with the strip behind the battery with the red tab protruding.

2.1 Rack Mounting

The P443/P446 may be specifically-ordered for rack mounting. The model number must have an "**N**" selection as the 10th digit, example:

P443xxxxx**N**xxxxx

The relay case has mounting flanges factory-fitted, with dimensions in accordance with IEC60297, to fit directly into a standard 483mm (19") rack system. The relay occupies the full width of the rack, with a tier height of 177mm (4U, equivalent to 7").

2.2 Panel Mounting

The P443/P446 may be specifically-ordered for panel mounting. The model number must have an “**M**” selection as the 10th digit, example:

P443xxxxx**M**xxxxx

The relays can be flush mounted into panels using M4 SEMS Taptite self-tapping screws with captive 3mm thick washers (also known as a SEMS unit). These fastenings are available in packs of 5 (our part number ZA0005 104).

Note: *Conventional self-tapping screws, including those supplied for mountingMIDOS relays, have marginally larger heads which can damage the front cover moulding if used.*

Alternatively tapped holes can be used if the panel has a minimum thickness of 2.5mm.

For applications where relays need to be semi-projection or projection mounted, a range of collars are available.

Where several relays are to mounted in a single cut-out in the panel, it is advised that they are mechanically grouped together horizontally and/or vertically to form rigid assemblies prior to mounting in the panel.

Note *Do not fasten MiCOM relays using pop rivets as this will not allow the relay to be easily removed from the panel in the future if repair is necessary.*

If it is required to mount a relay assembly on a panel complying to IEC 60529 IP52 enclosure protection, it will be necessary to fit a metallic sealing strip between adjoining relays (Part no GN2044 001) and a sealing ring around the complete assembly.

Width	Single Tier	Double Tier
80TE	GJ9018 016	GJ9018 032

Table 1 - Single and double tier sealing strips

2.3 Rack Mounting of Panel-Mount Versions

Versions of the P443/P446 that have been specified as panel-mount (10th digit of the order code set to M), can alternatively be mounted in a rack frame arrangement. The relay is mounted in a single tier rack frame (our part number FX0021 101) in an arrangement similar to Figure 2 although for the P443/P446, the relay will occupy the whole of the rack.

The rack frames have been designed to have dimensions in accordance with IEC60297 and are supplied pre-assembled ready to use.

The two horizontal rails of the rack frame have holes drilled at approximately 26mm intervals and the relays are attached via their mounting flanges using M4 Taptite self-tapping screws with captive 3mm thick washers (also known as a SEMS unit). These fastenings are available in packs of 5 (our part number ZA0005 104).

Note *Conventional self-tapping screws, including those supplied for mounting MiDOS relays, have marginally larger heads which can damage the front cover molding if used.*

The frames are fastened into the racks using mounting angles at each end of the tier.

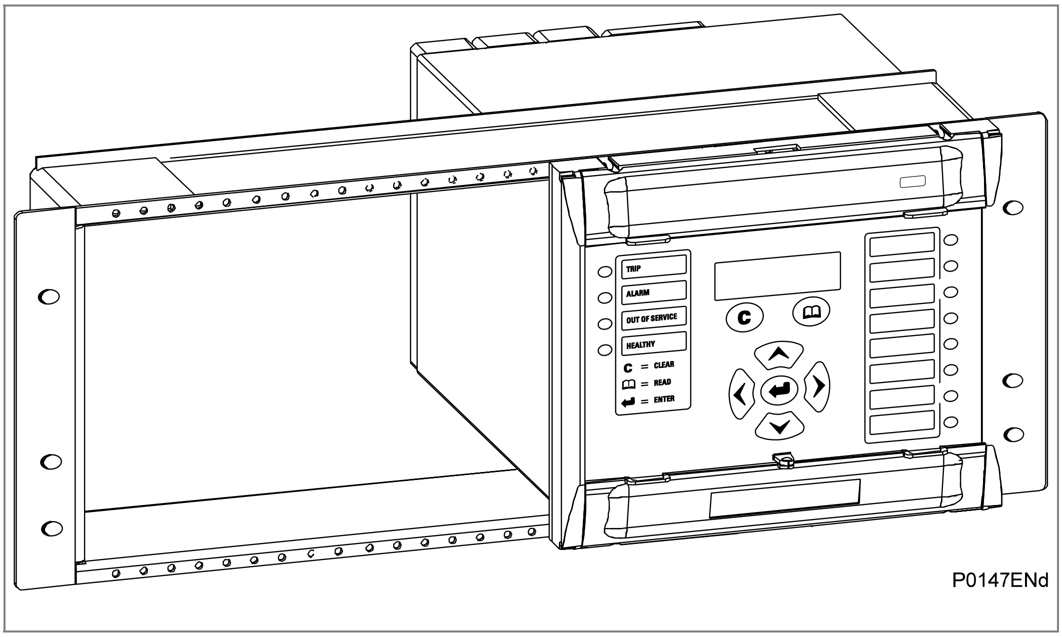

TRIP
ALARM
OUT OF SERVICE
HEALTHY
C = CLEAR
= READ
= ENTER
P0147ENd

Figure 2 - Rack mounting of panel-mount relays

3 RELAY WIRING

This section serves as a guide to selecting the appropriate cable and connector type for each terminal on the MiCOM relay.

3.1 Medium and Heavy Duty Terminal Block Connections

Key:

Heavy duty terminal block:	CT and VT circuits, terminals with “**D**” prefix
Medium duty:	All other terminal blocks (grey color)

Loose relays are supplied with sufficient M4 screws for making connections to the rear mounted terminal blocks using ring terminals, with a recommended maximum of two ring terminals per relay terminal.

If required, Schneider Electric can supply M4 90° crimp ring terminals in three different sizes depending on wire size (see Table 2). Each type is available in bags of 100.

Part Number	Wire Size	Insulation Color
ZB9124 901	0.25 - 1.65mm2 (22 - 16AWG)	Red
ZB9124 900	1.04 - 2.63mm2 (16 - 14AWG)	Blue
ZB9124 904	2.53 - 6.64mm2 (12 - 10AWG)	Un-insulated*
*To maintain the terminal block insulation requirements for safety, an insulating sleeve should be fitted over the ring terminal after crimping.		

Table 2 - Wire sizes and colours

The following minimum wire sizes are recommended:

Current Transformers	2.5mm^2
Auxiliary Supply, Vx	1.5mm^2
EIA(RS)485 Port	See separate section
Other Circuits	1.0mm^2

Due to the limitations of the ring terminal, the maximum wire size that can be used for any of the medium or heavy duty terminals is 6.0mm^2 using ring terminals that are not pre-insulated. Where it required to only use pre-insulated ring terminals, the maximum wire size that can be used is reduced to 2.63mm^2 per ring terminal. If a larger wire size is required, two wires should be used in parallel, each terminated in a separate ring terminal at the relay.

The wire used for all connections to the medium and heavy duty terminal blocks, except the EIA(RS)485 port, should have a minimum voltage rating of 300Vrms.

It is recommended that the auxiliary supply wiring should be protected by a 16A High Rupture Capacity (HRC) fuse of type NIT or TIA. For safety reasons, current transformer circuits must never be fused. Other circuits should be appropriately fused to protect the wire used.

Note	*The high-break contacts optionally fitted in P443/P446 relays are polarity sensitive. External wiring must respect the polarity requirements which are shown on the external connection diagram to ensure correct operation.*

3.2 EIA(RS)485 Port

Connections to the EIA(RS)485 port are made using ring terminals. It is recommended that a 2 core screened cable is used with a maximum total length of 1000m or 200nF total cable capacitance. A typical cable specification would be:

Each core:	16/0.2mm copper conductors PVC insulated
Nominal conductor area:	0.5mm^2 per core
Screen:	Overall braid, PVC sheathed

3.3 IRIG-B Connections (if applicable)

The IRIG-B input and BNC connector have a characteristic impedance of 50Ω. It is recommended that connections between the IRIG-B equipment and the relay are made using coaxial cable of type RG59LSF with a halogen free, fire retardant sheath.

3.4 EIA(RS)232 Front Port

Short term connections to the EIA(RS)485 port, located behind the bottom access cover, can be made using a screened multi-core communication cable up to 15m long, or a total capacitance of 2500pF. The cable should be terminated at the relay end with a 9-way, metal shelled, D-type male plug. The pin allocations are detailed in Getting Started (P44y/EN GS).

3.5 Ethernet Port for IEC 61850 (if applicable)

3.5.1 Fiber Optic Port

The relays can have 100 Mbps Ethernet port. Fiber optic connection is recommended for use in permanent connections in a substation environment. The 100Mbit port uses type ST connector, compatible with fiber multimode 50/125µm or 62.5/125µm - 1300nm.

3.5.2 RJ-45 Metallic Port

The user can connect to either a 10Base-T or a 100Base-TX Ethernet hub; the port will automatically sense which type of hub is connected. Due to possibility of noise and interference on this part, it is recommended that this connection type be used for short-term connections and over short distance. Ideally, where the relays and hubs are located in the same cubicle.
The connector for the Ethernet port is a shielded RJ-45. Table 3 shows the signals and pins on the connector.

Pin	Signal Name	Signal Definition
1	TXP	Transmit (positive)
2	TXN	Transmit (negative)
3	RXP	Receive (positive)
4	-	Not used
5	-	Not used
6	RXN	Receive (negative)
7	-	Not used
8	-	Not used

Table 3 - Signals on the Ethernet connector

3.6 Ethernet Port for DNP3.0 (if applicable)

3.6.1 Fiber Optic Port

The relays can have 100 Mbps Ethernet port. Fiber optic connection is recommended for use in permanent connections in a substation environment. The 100Mbit port uses type ST (BFOC2.5) connectors, compatible with 50/125µm or 62.5/125µm multimode fibers for use at 1300nm wavelength.

3.6.2 RJ-45 Metallic Port

The user can connect to either a 10Base-T or a 100Base-TX Ethernet hub; the port will automatically sense which type of hub is connected. Due to possibility of noise and interference on this part, it is recommended that this connection type be used for short-term connections and over short distances. Ideally, the relays and hubs should be located in the same cubicle.

The connector for the Ethernet port is a shielded RJ-45. Table 4 shows the signals and pins on the connector.

Pin	Signal Name	Signal Definition
1	TXP	Transmit (positive)
2	TXN	Transmit (negative)
3	RXP	Receive (positive)
4	-	Not used
5	-	Not used
6	RXN	Receive (negative)
7	-	Not used
8	-	Not used

Table 4 - Signals on the Ethernet connector

3.7 Download/Monitor Port

Short term connections to the download/monitor port, located behind the bottom access cover, can be made using a screened 25-core communication cable up to 4m long. The cable should be terminated at the relay end with a 25-way, metal-shelled, D-type male plug.

3.8 Earth Connection

Every relay must be connected to the cubicle earth bar using the M4 earth studs in the bottom left hand corner of the relay case. The minimum recommended wire size is 2.5mm^2 and should have a ring terminal at the relay end.

To prevent any possibility of electrolytic action between brass or copper earth conductors and the rear of the relay, precautions should be taken. Examples include placing a nickel-plated washer between the conductor and the relay case, or using tinned ring terminals.

4 P443/P446 CASE DIMENSIONS

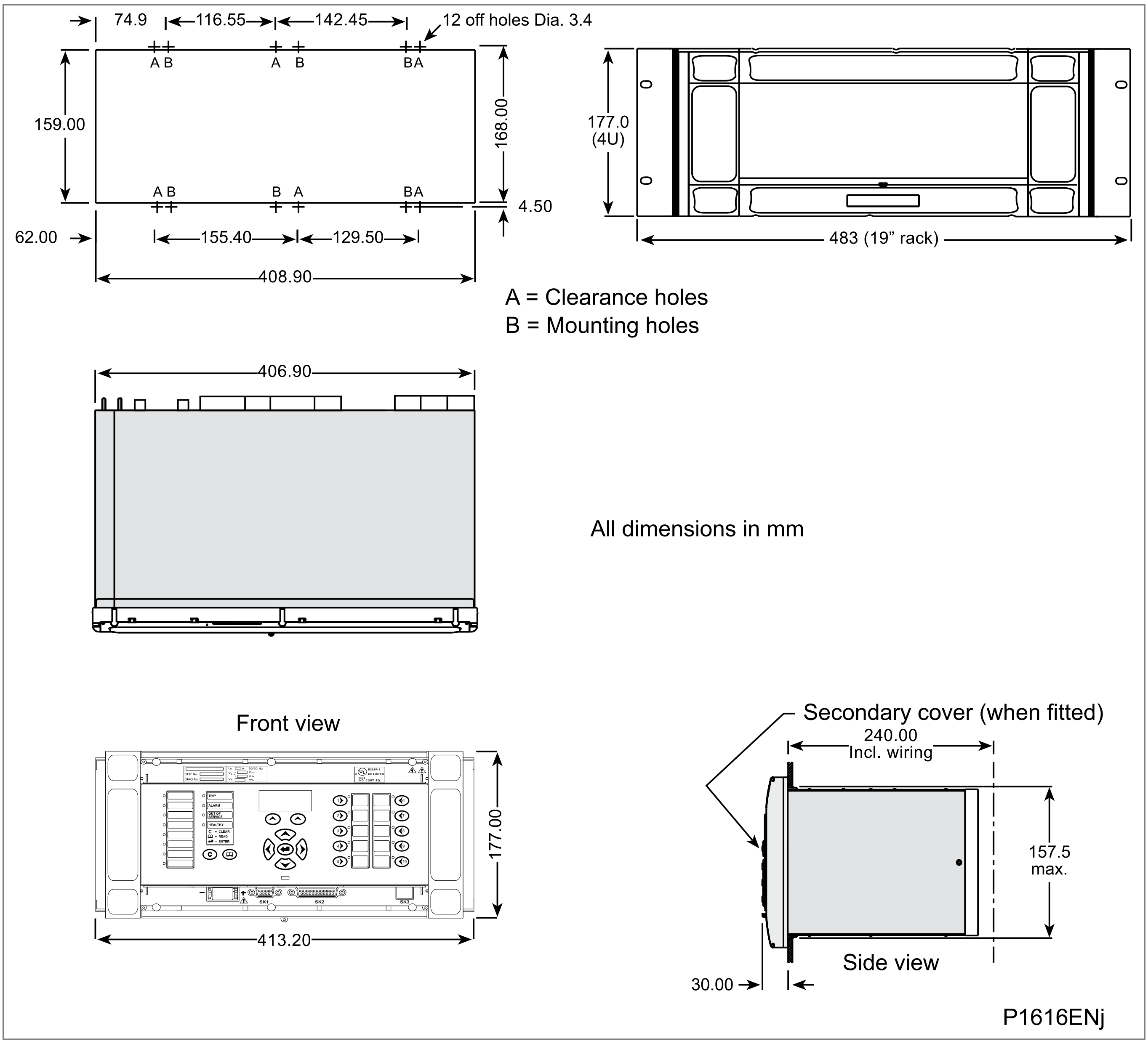

74.9
116.55
142.45
12 off holes Dia. 3.4
A B
A B
B A
159.00
168.00
A B
B A
B A
4.50
62.00
155.40
129.50
408.90
177.0
(4U)
483 (19" rack)
A = Clearance holes
B = Mounting holes
406.90
All dimensions in mm
Front view
177.00
413.20
Secondary cover (when fitted)
240.00
Incl. wiring
157.5
max.
Side view
30.00
P1616ENj

Figure 3 - P443/P446 case dimensions - 80TE case

5 P443/P446 2ND REAR COMMS BOARD CONNECTIONS

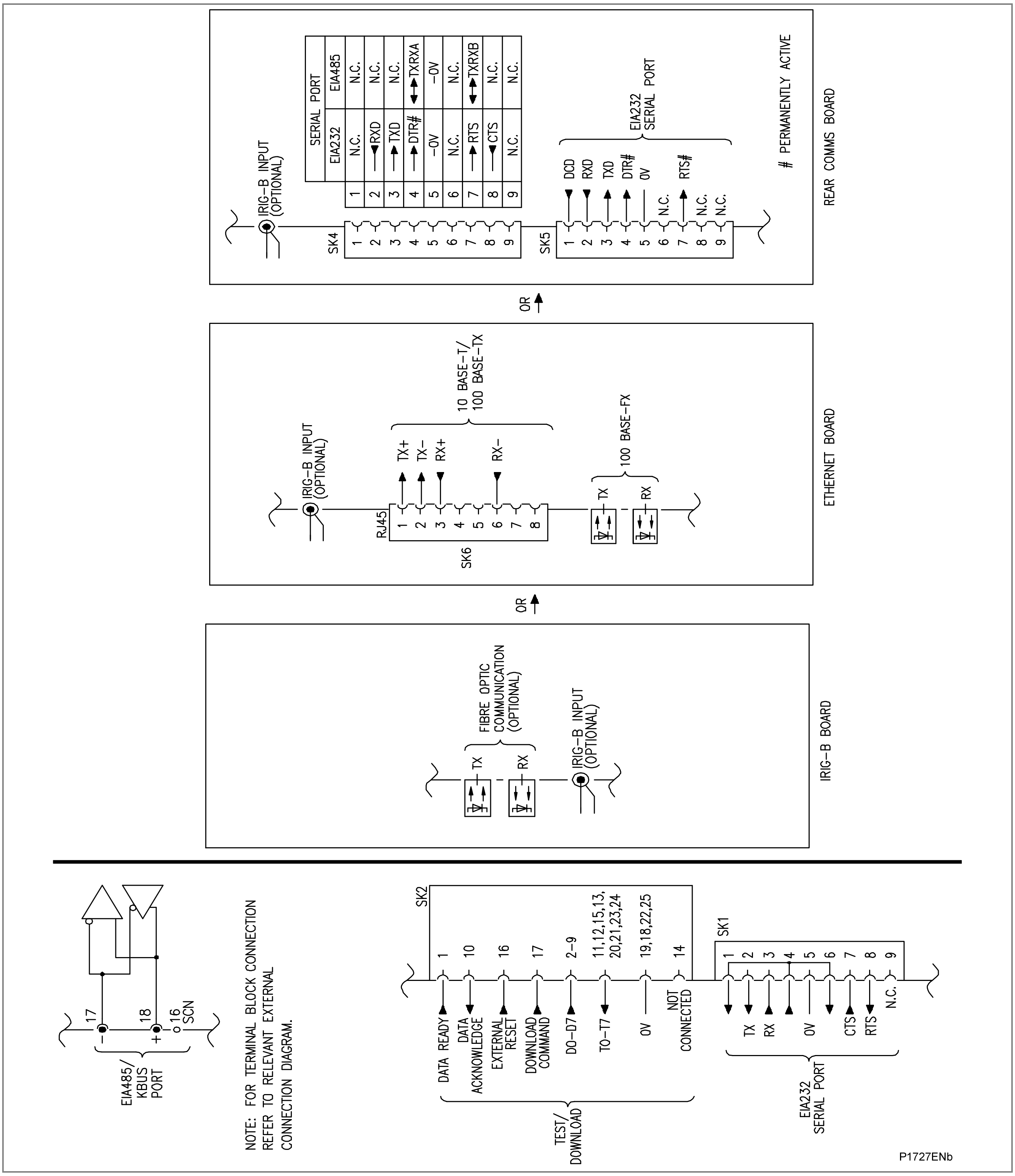
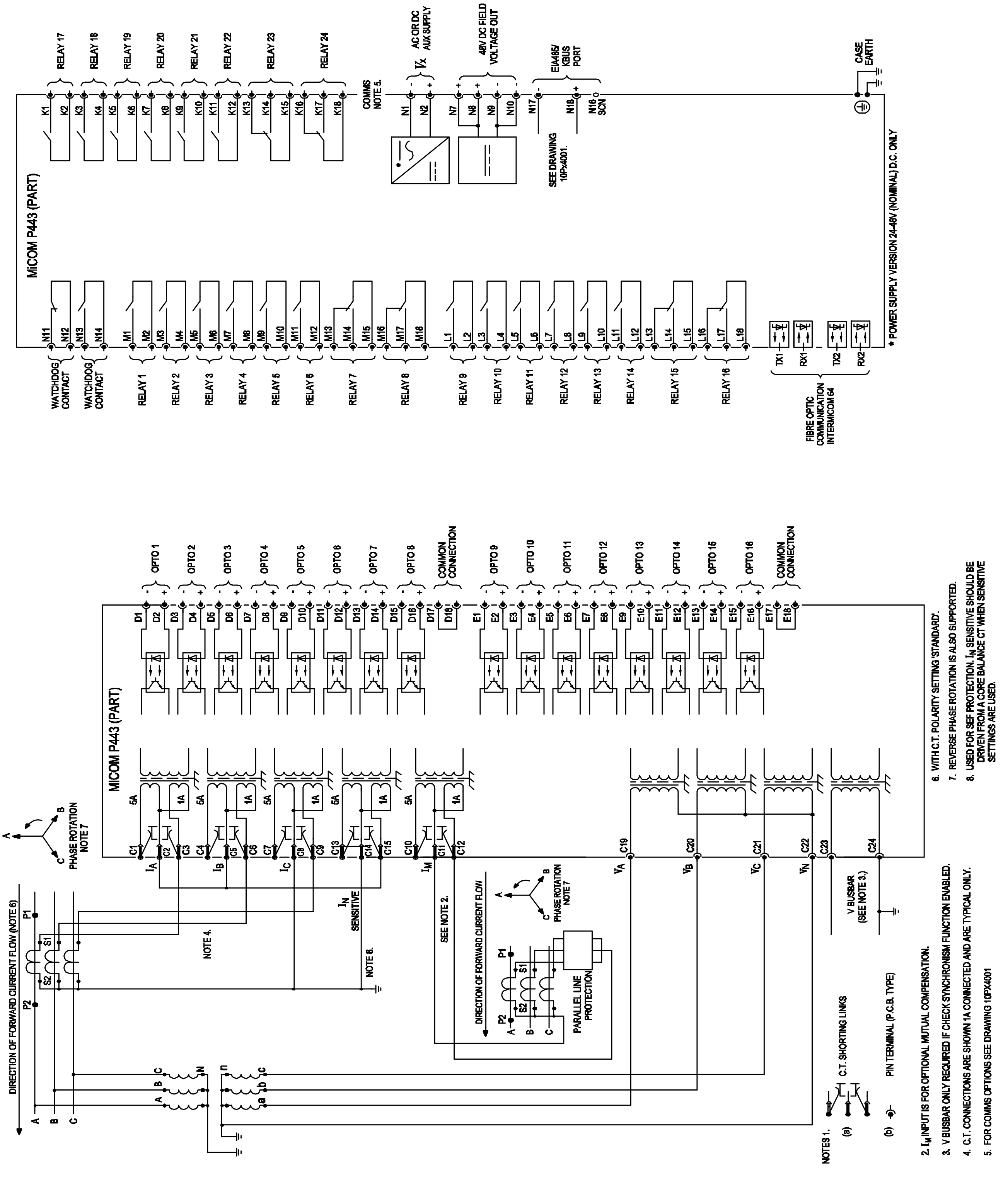

REAR COMMS BOARD
# PERMANENTLY ACTIVE
SERIAL PORT
EIA232
EIA485
1 N.C. N.C.
2 RXD N.C.
3 TXD N.C.
4 DTR# TXRXA
5 -0V -0V
6 N.C. N.C.
7 RTS TXRXB
8 CTS N.C.
9 N.C. N.C.
IRIG-B INPUT (OPTIONAL)
SK4
1 2 3 4 5 6 7 8 9
EIA232 SERIAL PORT
DCD RXD TXD DTR# 0V N.C. RTS# N.C. N.C.
SK5
1 2 3 4 5 6 7 8 9
OR
ETHERNET BOARD
IRIG-B INPUT (OPTIONAL)
10 BASE-T/ 100 BASE-TX
TX+ TX- RX+ RX-
RJ45
1 2 3 4 5 6 7 8
SK6
100 BASE-FX
TX RX
OR
IRIG-B BOARD
FIBRE OPTIC COMMUNICATION (OPTIONAL)
TX RX
IRIG-B INPUT (OPTIONAL)
17 18 16
- + SCN
EIA485/ KBUS PORT
NOTE: FOR TERMINAL BLOCK CONNECTION REFER TO RELEVANT EXTERNAL CONNECTION DIAGRAM.
SK2
1 10 16 17 2-9 11,12,15,13, 20,21,23,24 19,18,22,25 14
DATA READY
DATA ACKNOWLEDGE
EXTERNAL RESET
DOWNLOAD COMMAND
D0-D7
T0-T7
0V
NOT CONNECTED
TEST/ DOWNLOAD
SK1
1 2 3 4 5 6 7 8 9
TX RX 0V CTS RTS N.C.
EIA232 SERIAL PORT
P1727ENb

Figure 4 - P443/P446 second rear port connections

6 P443/P446 EXTERNAL CONNECTION DIAGRAMS


MiCOM P443 (PART)
RELAY 17
RELAY 18
RELAY 19
RELAY 20
RELAY 21
RELAY 22
RELAY 23
RELAY 24
COMMS NOTE 5.
AC OR DC AUX SUPPLY
Vx
48V DC FIELD VOLTAGE OUT
EIA485/ KBUS PORT
SEE DRAWING 10Px4001.
CASE EARTH
WATCHDOG CONTACT
RELAY 1
RELAY 2
RELAY 3
RELAY 4
RELAY 5
RELAY 6
RELAY 7
RELAY 8
RELAY 9
RELAY 10
RELAY 11
RELAY 12
RELAY 13
RELAY 14
RELAY 15
RELAY 16
TX1
RX1
TX2
RX2
FIBRE OPTIC COMMUNICATION INTERMICOM 64
OPTO 1
OPTO 2
OPTO 3
OPTO 4
OPTO 5
OPTO 6
OPTO 7
OPTO 8
COMMON CONNECTION
OPTO 9
OPTO 10
OPTO 11
OPTO 12
OPTO 13
OPTO 14
OPTO 15
OPTO 16
PHASE ROTATION NOTE 7
DIRECTION OF FORWARD CURRENT FLOW (NOTE 6)
NOTE 4.
IN SENSITIVE
NOTE 8.
SEE NOTE 2.
PARALLEL LINE PROTECTION
V BUSBAR (SEE NOTE 3.)
5A
1A
IA
IB
IC
IM
VA
VB
VC
VN
P1
P2
S1
S2
A
B
C

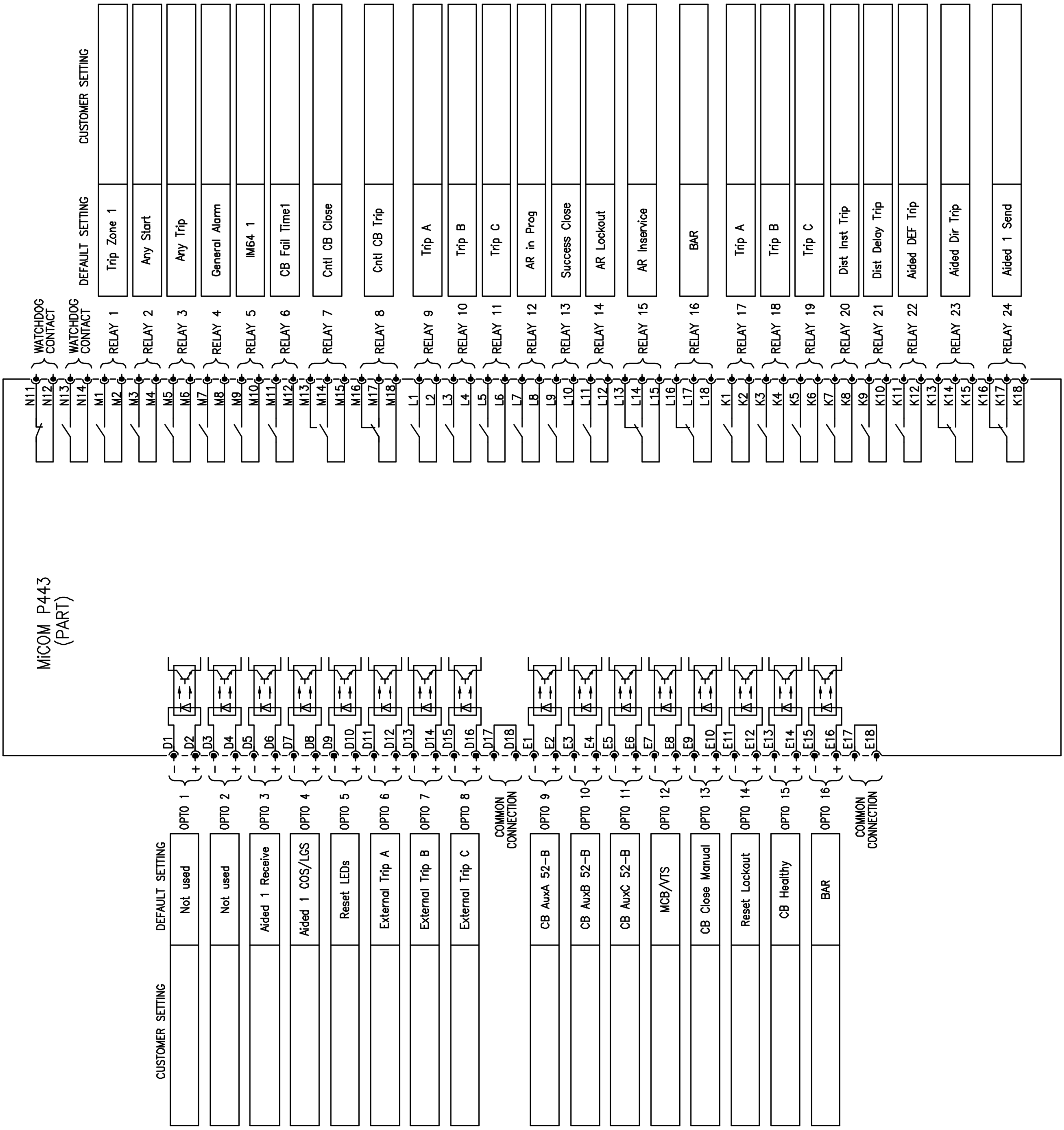
* POWER SUPPLY VERSION 24-48V (NOMINAL) D.C. ONLY

NOTES 1.
(a) C.T. SHORTING LINKS
(b) PIN TERMINAL (P.C.B. TYPE)
2. I_M INPUT IS FOR OPTIONAL MUTUAL COMPENSATION.
3. V BUSBAR ONLY REQUIRED IF CHECK SYNCHRONISM FUNCTION ENABLED.
4. C.T. CONNECTIONS ARE SHOWN 1A CONNECTED AND ARE TYPICAL ONLY.
5. FOR COMMS OPTIONS SEE DRAWING 10PX4001
6. WITH C.T. POLARITY SETTING 'STANDARD'.
7. REVERSE PHASE ROTATION IS ALSO SUPPORTED.
8. USED FOR SEF PROTECTION. I_N SENSITIVE SHOULD BE DRIVEN FROM A CORE BALANCE CT WHEN SENSITIVE SETTINGS ARE USED.

Based on 10P44304 Sheet 1 Issue B

P0315ENa

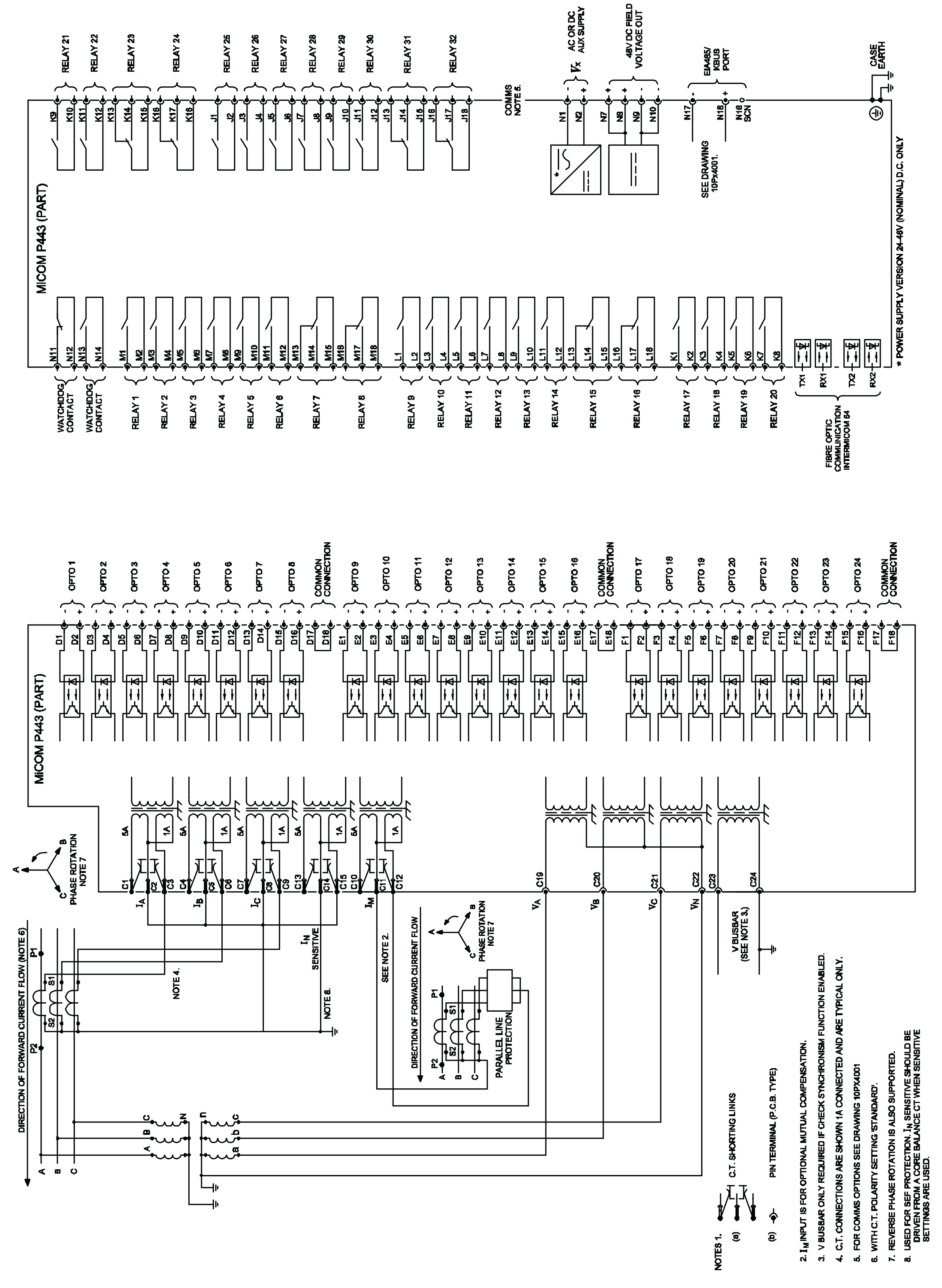
Figure 5 - P443 A external connections (80TE) - standard relay outputs 16I/P & 24 O/P


CUSTOMER SETTING
DEFAULT SETTING
Trip Zone 1
Any Start
Any Trip
General Alarm
IM64 1
CB Fail Time1
Cntl CB Close
Cntl CB Trip
Trip A
Trip B
Trip C
AR in Prog
Success Close
AR Lockout
AR Inservice
BAR
Trip A
Trip B
Trip C
Dist Inst Trip
Dist Delay Trip
Aided DEF Trip
Aided Dir Trip
Aided 1 Send
WATCHDOG CONTACT
WATCHDOG CONTACT
RELAY 1
RELAY 2
RELAY 3
RELAY 4
RELAY 5
RELAY 6
RELAY 7
RELAY 8
RELAY 9
RELAY 10
RELAY 11
RELAY 12
RELAY 13
RELAY 14
RELAY 15
RELAY 16
RELAY 17
RELAY 18
RELAY 19
RELAY 20
RELAY 21
RELAY 22
RELAY 23
RELAY 24
N11 N12 N13 N14 M1 M2 M3 M4 M5 M6 M7 M8 M9 M10 M11 M12 M13 M14 M15 M16 M17 M18
L1 L2 L3 L4 L5 L6 L7 L8 L9 L10 L11 L12 L13 L14 L15 L16 L17 L18
K1 K2 K3 K4 K5 K6 K7 K8 K9 K10 K11 K12 K13 K14 K15 K16 K17 K18
MiCOM P443
(PART)
D1 D2 D3 D4 D5 D6 D7 D8 D9 D10 D11 D12 D13 D14 D15 D16 D17 D18
E1 E2 E3 E4 E5 E6 E7 E8 E9 E10 E11 E12 E13 E14 E15 E16 E17 E18
- +
OPTO 1
OPTO 2
OPTO 3
OPTO 4
OPTO 5
OPTO 6
OPTO 7
OPTO 8
COMMON CONNECTION
OPTO 9
OPTO 10
OPTO 11
OPTO 12
OPTO 13
OPTO 14
OPTO 15
OPTO 16
COMMON CONNECTION
DEFAULT SETTING
Not used
Not used
Aided 1 Receive
Aided 1 COS/LGS
Reset LEDs
External Trip A
External Trip B
External Trip C
CB AuxA 52-B
CB AuxB 52-B
CB AuxC 52-B
MCB/VTS
CB Close Manual
Reset Lockout
CB Healthy
BAR
CUSTOMER SETTING

Based on 10P44304 Sheet 3 Issue B

P0316ENa

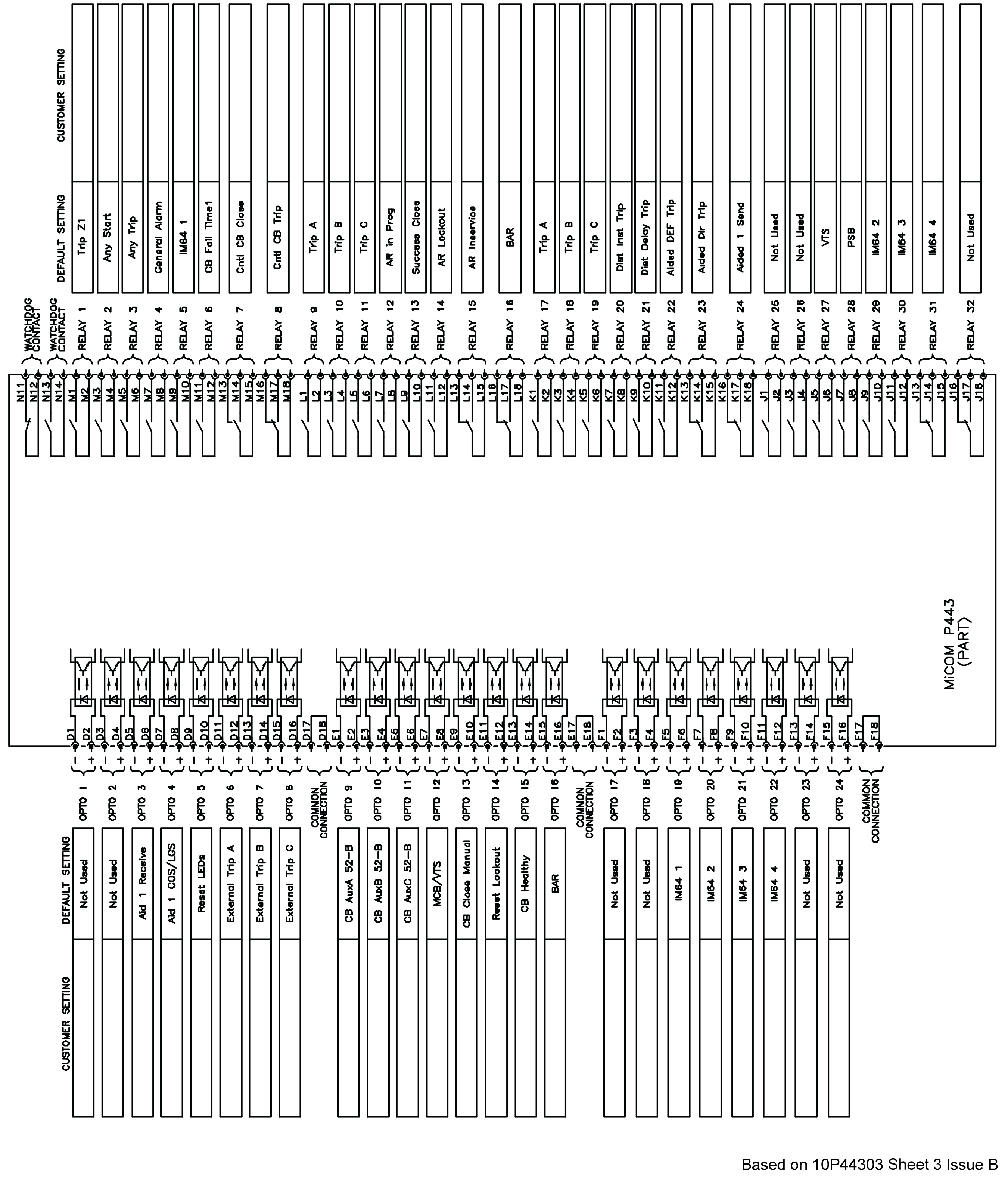
Figure 6 - P443 A external connections (80TE) - inputs/outputs default mapping - standard relay outputs 16 I/P & 24 O/P


MICOM P443 (PART)
RELAY 21
RELAY 22
RELAY 23
RELAY 24
RELAY 25
RELAY 26
RELAY 27
RELAY 28
RELAY 29
RELAY 30
RELAY 31
RELAY 32
COMMS NOTE 5.
AC OR DC AUX SUPPLY
Vx
48V DC FIELD VOLTAGE OUT
EIA485/ KBUS PORT
SEE DRAWING 10Px4001.
N18 SCN
CASE EARTH
* POWER SUPPLY VERSION 24-48V (NOMINAL) D.C. ONLY
WATCHDOG CONTACT
WATCHDOG CONTACT
RELAY 1
RELAY 2
RELAY 3
RELAY 4
RELAY 5
RELAY 6
RELAY 7
RELAY 8
RELAY 9
RELAY 10
RELAY 11
RELAY 12
RELAY 13
RELAY 14
RELAY 15
RELAY 16
RELAY 17
RELAY 18
RELAY 19
RELAY 20
TX1
RX1
TX2
RX2
FIBRE OPTIC COMMUNICATION INTERMICOM 64
OPTO 1
OPTO 2
OPTO 3
OPTO 4
OPTO 5
OPTO 6
OPTO 7
OPTO 8
COMMON CONNECTION
OPTO 9
OPTO 10
OPTO 11
OPTO 12
OPTO 13
OPTO 14
OPTO 15
OPTO 16
COMMON CONNECTION
OPTO 17
OPTO 18
OPTO 19
OPTO 20
OPTO 21
OPTO 22
OPTO 23
OPTO 24
COMMON CONNECTION
PHASE ROTATION NOTE 7
DIRECTION OF FORWARD CURRENT FLOW (NOTE 6)
P1
P2
S1
S2
NOTE 4.
IN SENSITIVE
NOTE 8.
SEE NOTE 2.
DIRECTION OF FORWARD CURRENT FLOW
PARALLEL LINE PROTECTION
IA
IB
IC
IM
VA
VB
VC
VN
V BUSBAR (SEE NOTE 3.)
5A
1A
NOTES 1.
(a) C.T. SHORTING LINKS
(b) PIN TERMINAL (P.C.B. TYPE)
2. IM INPUT IS FOR OPTIONAL MUTUAL COMPENSATION.
3. V BUSBAR ONLY REQUIRED IF CHECK SYNCHRONISM FUNCTION ENABLED.
4. C.T. CONNECTIONS ARE SHOWN 1A CONNECTED AND ARE TYPICAL ONLY.
5. FOR COMMS OPTIONS SEE DRAWING 10PX4001
6. WITH C.T. POLARITY SETTING 'STANDARD'.
7. REVERSE PHASE ROTATION IS ALSO SUPPORTED.
8. USED FOR SEF PROTECTION. IN SENSITIVE SHOULD BE DRIVEN FROM A CORE BALANCE CT WHEN SENSITIVE SETTINGS ARE USED.

Based on 10P44303 Sheet 1 Issue B

P0317ENa

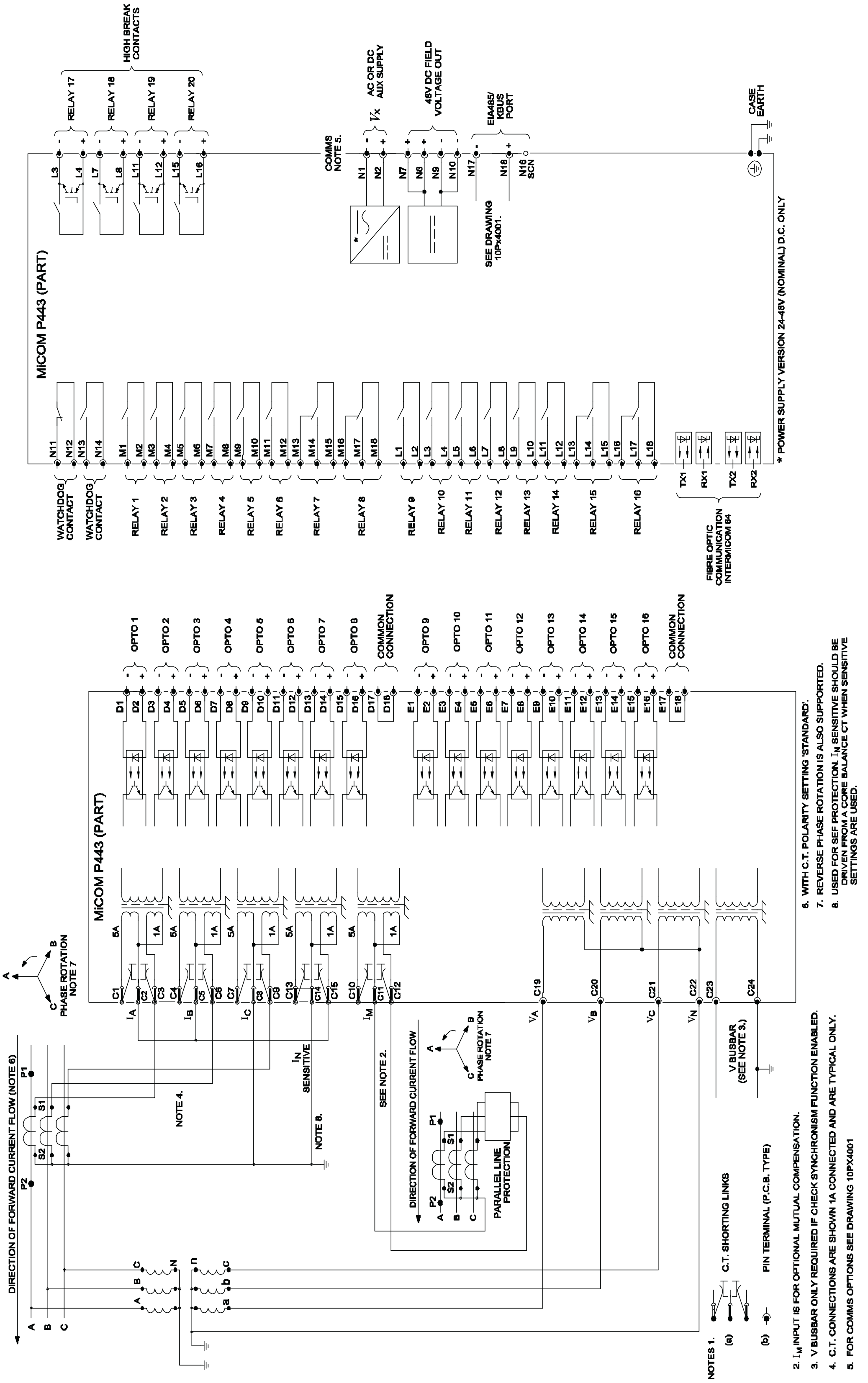
Figure 7 - P443 B external connections (80TE) - standard relay outputs 24 I/P & 32 O/P


CUSTOMER SETTING
DEFAULT SETTING
WATCHDOG CONTACT N11 N12
WATCHDOG CONTACT N13 N14
RELAY 1 M1 M2 Trip Z1
RELAY 2 M3 M4 Any Start
RELAY 3 M5 M6 Any Trip
RELAY 4 M7 M8 General Alarm
RELAY 5 M9 M10 IM64 1
RELAY 6 M11 M12 CB Fail Time1
RELAY 7 M13 M14 M15 Cntl CB Close
RELAY 8 M16 M17 M18 Cntl CB Trip
RELAY 9 L1 L2 Trip A
RELAY 10 L3 L4 Trip B
RELAY 11 L5 L6 Trip C
RELAY 12 L7 L8 AR in Prog
RELAY 13 L9 L10 Success Close
RELAY 14 L11 L12 AR Lockout
RELAY 15 L13 L14 L15 AR Inservice
RELAY 16 L16 L17 L18 BAR
RELAY 17 K1 K2 Trip A
RELAY 18 K3 K4 Trip B
RELAY 19 K5 K6 Trip C
RELAY 20 K7 K8 Dist Inst Trip
RELAY 21 K9 K10 Dist Delay Trip
RELAY 22 K11 K12 Aided DEF Trip
RELAY 23 K13 K14 K15 Aided Dir Trip
RELAY 24 K16 K17 K18 Aided 1 Send
RELAY 25 J1 J2 Not Used
RELAY 26 J3 J4 Not Used
RELAY 27 J5 J6 VTS
RELAY 28 J7 J8 PSB
RELAY 29 J9 J10 IM64 2
RELAY 30 J11 J12 IM64 3
RELAY 31 J13 J14 J15 IM64 4
RELAY 32 J16 J17 J18 Not Used
MiCOM P443 (PART)
OPTO 1 D1 D2 - + Not Used
OPTO 2 D3 D4 - + Not Used
OPTO 3 D5 D6 - + Aid 1 Receive
OPTO 4 D7 D8 - + Aid 1 COS/LGS
OPTO 5 D9 D10 - + Reset LEDs
OPTO 6 D11 D12 - + External Trip A
OPTO 7 D13 D14 - + External Trip B
OPTO 8 D15 D16 - + External Trip C
COMMON CONNECTION D17 D18
OPTO 9 E1 E2 - + CB AuxA 52-B
OPTO 10 E3 E4 - + CB AuxB 52-B
OPTO 11 E5 E6 - + CB AuxC 52-B
OPTO 12 E7 E8 - + MCB/VTS
OPTO 13 E9 E10 - + CB Close Manual
OPTO 14 E11 E12 - + Reset Lockout
OPTO 15 E13 E14 - + CB Healthy
OPTO 16 E15 E16 - + BAR
COMMON CONNECTION E17 E18
OPTO 17 F1 F2 - + Not Used
OPTO 18 F3 F4 - + Not Used
OPTO 19 F5 F6 - + IM64 1
OPTO 20 F7 F8 - + IM64 2
OPTO 21 F9 F10 - + IM64 3
OPTO 22 F11 F12 - + IM64 4
OPTO 23 F13 F14 - + Not Used
OPTO 24 F15 F16 - + Not Used
COMMON CONNECTION F17 F18

Based on 10P44303 Sheet 3 Issue B

P0318ENa

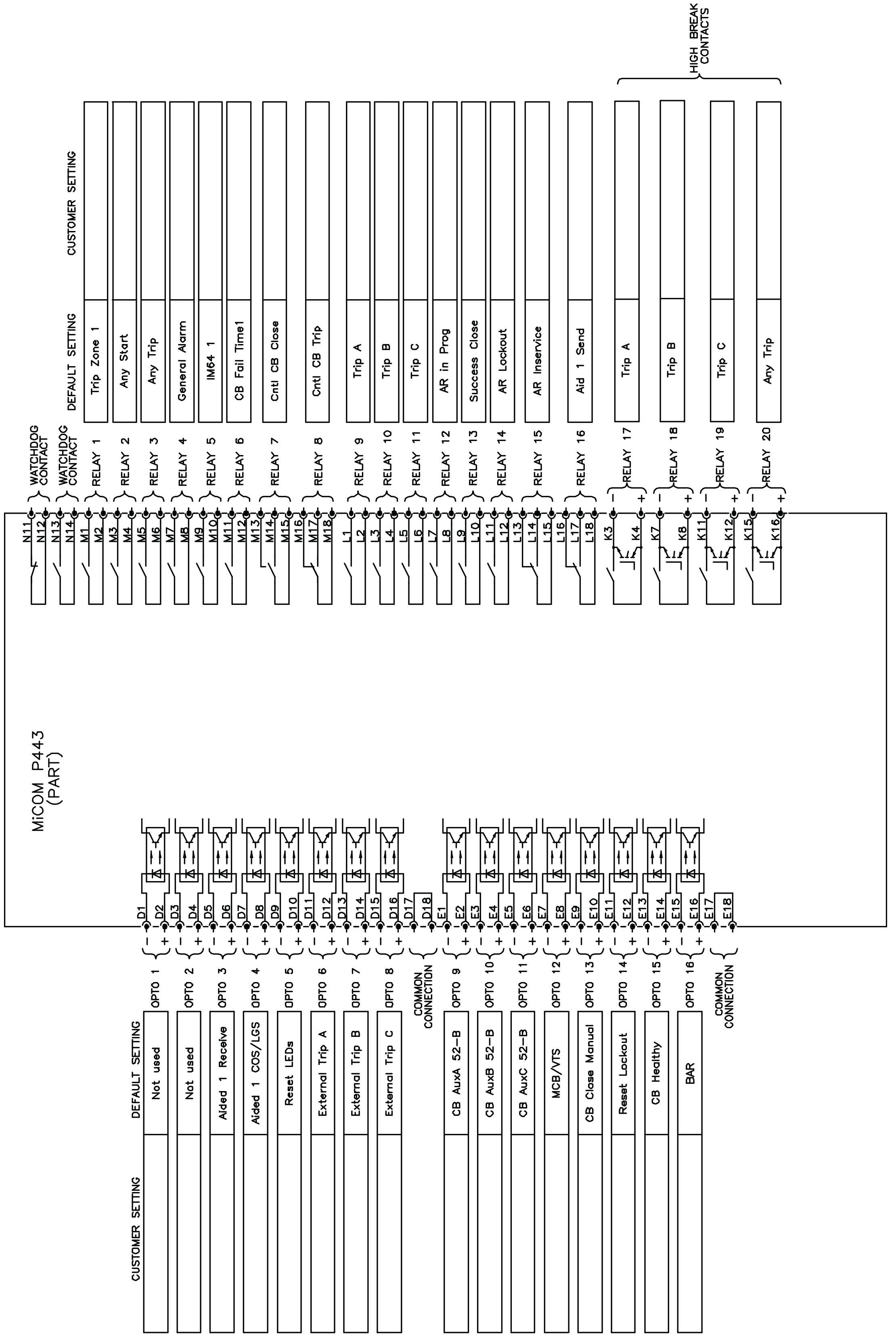
Figure 8 - P443 B external connections (80TE) - inputs/outputs default mapping - standard relay outputs 24 I/P & 32 O/P


MiCOM P443 (PART)
HIGH BREAK CONTACTS
RELAY 17
RELAY 18
RELAY 19
RELAY 20
COMMS NOTE 5.
AC OR DC AUX SUPPLY
Vx
48V DC FIELD VOLTAGE OUT
EIA485/ KBUS PORT
SCN
SEE DRAWING 10Px4001.
CASE EARTH
* POWER SUPPLY VERSION 24-48V (NOMINAL) D.C. ONLY
WATCHDOG CONTACT
WATCHDOG CONTACT
RELAY 1
RELAY 2
RELAY 3
RELAY 4
RELAY 5
RELAY 6
RELAY 7
RELAY 8
RELAY 9
RELAY 10
RELAY 11
RELAY 12
RELAY 13
RELAY 14
RELAY 15
RELAY 16
TX1
RX1
TX2
RX2
FIBRE OPTIC COMMUNICATION INTERMICOM 64
OPTO 1
OPTO 2
OPTO 3
OPTO 4
OPTO 5
OPTO 6
OPTO 7
OPTO 8
COMMON CONNECTION
OPTO 9
OPTO 10
OPTO 11
OPTO 12
OPTO 13
OPTO 14
OPTO 15
OPTO 16
COMMON CONNECTION
PHASE ROTATION NOTE 7
5A
1A
IA
IB
IC
IM
VA
VB
VC
VN
V BUSBAR (SEE NOTE 3.)
IN SENSITIVE
NOTE 4.
NOTE 8.
SEE NOTE 2.
DIRECTION OF FORWARD CURRENT FLOW (NOTE 6)
DIRECTION OF FORWARD CURRENT FLOW
PARALLEL LINE PROTECTION
P1
P2
S1
S2
A
B
C
N
a
b
c
n
NOTES 1.
(a) C.T. SHORTING LINKS
(b) PIN TERMINAL (P.C.B. TYPE)
2. IM INPUT IS FOR OPTIONAL MUTUAL COMPENSATION.
3. V BUSBAR ONLY REQUIRED IF CHECK SYNCHRONISM FUNCTION ENABLED.
4. C.T. CONNECTIONS ARE SHOWN 1A CONNECTED AND ARE TYPICAL ONLY.
5. FOR COMMS OPTIONS SEE DRAWING 10PX4001
6. WITH C.T. POLARITY SETTING 'STANDARD'.
7. REVERSE PHASE ROTATION IS ALSO SUPPORTED.
8. USED FOR SEF PROTECTION. IN SENSITIVE SHOULD BE DRIVEN FROM A CORE BALANCE CT WHEN SENSITIVE SETTINGS ARE USED.

Based on 10P44306 Sheet 1 Issue B

P0319ENa

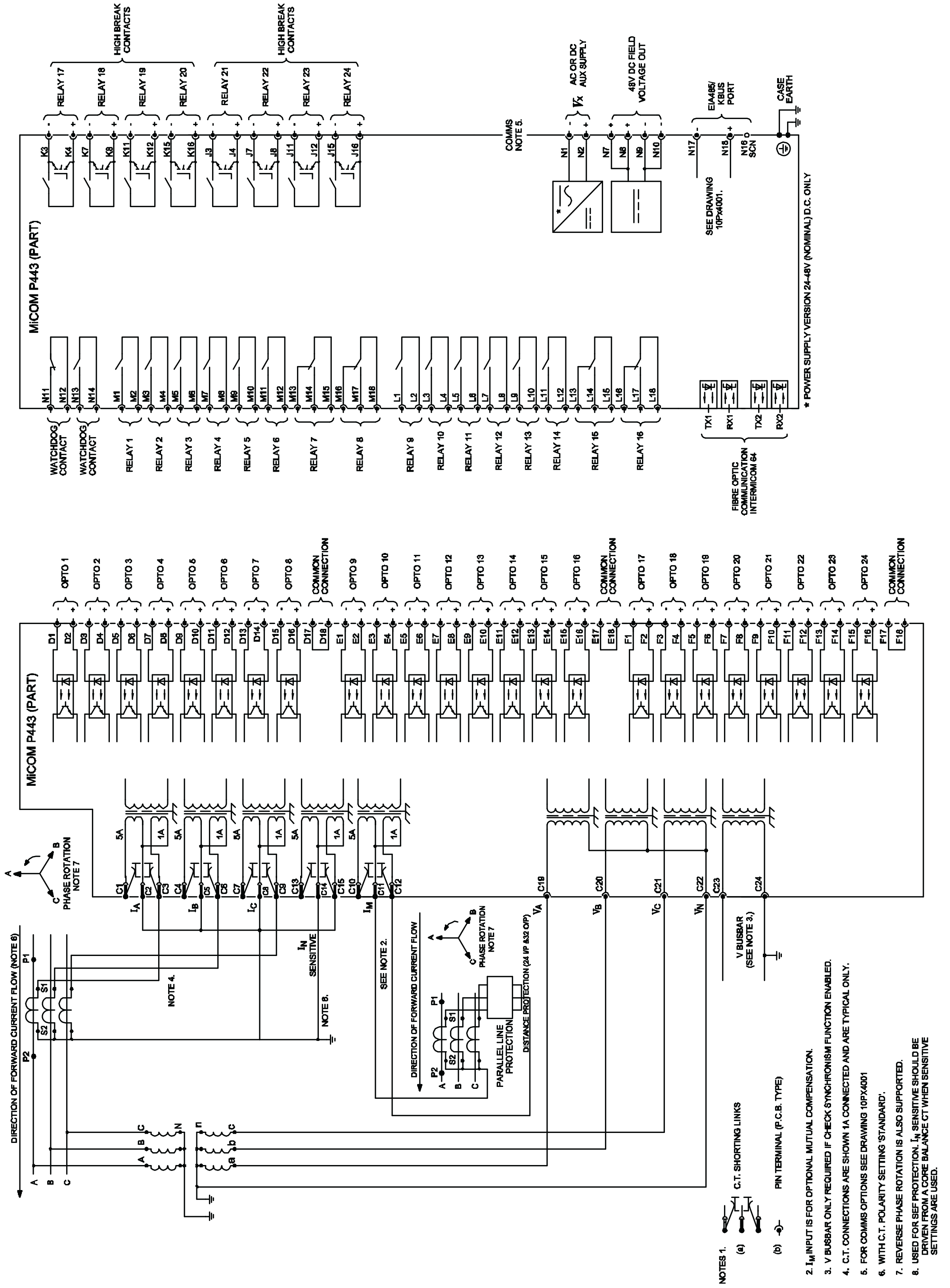
Figure 9 - P443 C external connections (80TE) - high break relay outputs - 16 I/P & 20 I/P


HIGH BREAK CONTACTS
CUSTOMER SETTING
DEFAULT SETTING
Trip Zone 1
Any Start
Any Trip
General Alarm
IM64 1
CB Fail Time1
Cntl CB Close
Cntl CB Trip
Trip A
Trip B
Trip C
AR in Prog
Success Close
AR Lockout
AR Inservice
Aid 1 Send
Trip A
Trip B
Trip C
Any Trip
WATCHDOG CONTACT
WATCHDOG CONTACT
RELAY 1
RELAY 2
RELAY 3
RELAY 4
RELAY 5
RELAY 6
RELAY 7
RELAY 8
RELAY 9
RELAY 10
RELAY 11
RELAY 12
RELAY 13
RELAY 14
RELAY 15
RELAY 16
RELAY 17
RELAY 18
RELAY 19
RELAY 20
N11 N12 N13 N14
M1 M2 M3 M4 M5 M6 M7 M8 M9 M10 M11 M12 M13 M14 M15 M16 M17 M18
L1 L2 L3 L4 L5 L6 L7 L8 L9 L10 L11 L12 L13 L14 L15 L16 L17 L18
K3 K4 K7 K8 K11 K12 K15 K16
MiCOM P443 (PART)
D1 D2 D3 D4 D5 D6 D7 D8 D9 D10 D11 D12 D13 D14 D15 D16 D17 D18
E1 E2 E3 E4 E5 E6 E7 E8 E9 E10 E11 E12 E13 E14 E15 E16 E17 E18
OPTO 1
OPTO 2
OPTO 3
OPTO 4
OPTO 5
OPTO 6
OPTO 7
OPTO 8
COMMON CONNECTION
OPTO 9
OPTO 10
OPTO 11
OPTO 12
OPTO 13
OPTO 14
OPTO 15
OPTO 16
COMMON CONNECTION
DEFAULT SETTING
Not used
Not used
Aided 1 Receive
Aided 1 COS/LGS
Reset LEDs
External Trip A
External Trip B
External Trip C
CB AuxA 52–B
CB AuxB 52–B
CB AuxC 52–B
MCB/VTS
CB Close Manual
Reset Lockout
CB Healthy
BAR
CUSTOMER SETTING

Based on 10P44306 Sheet 3 Issue B

P0320ENa

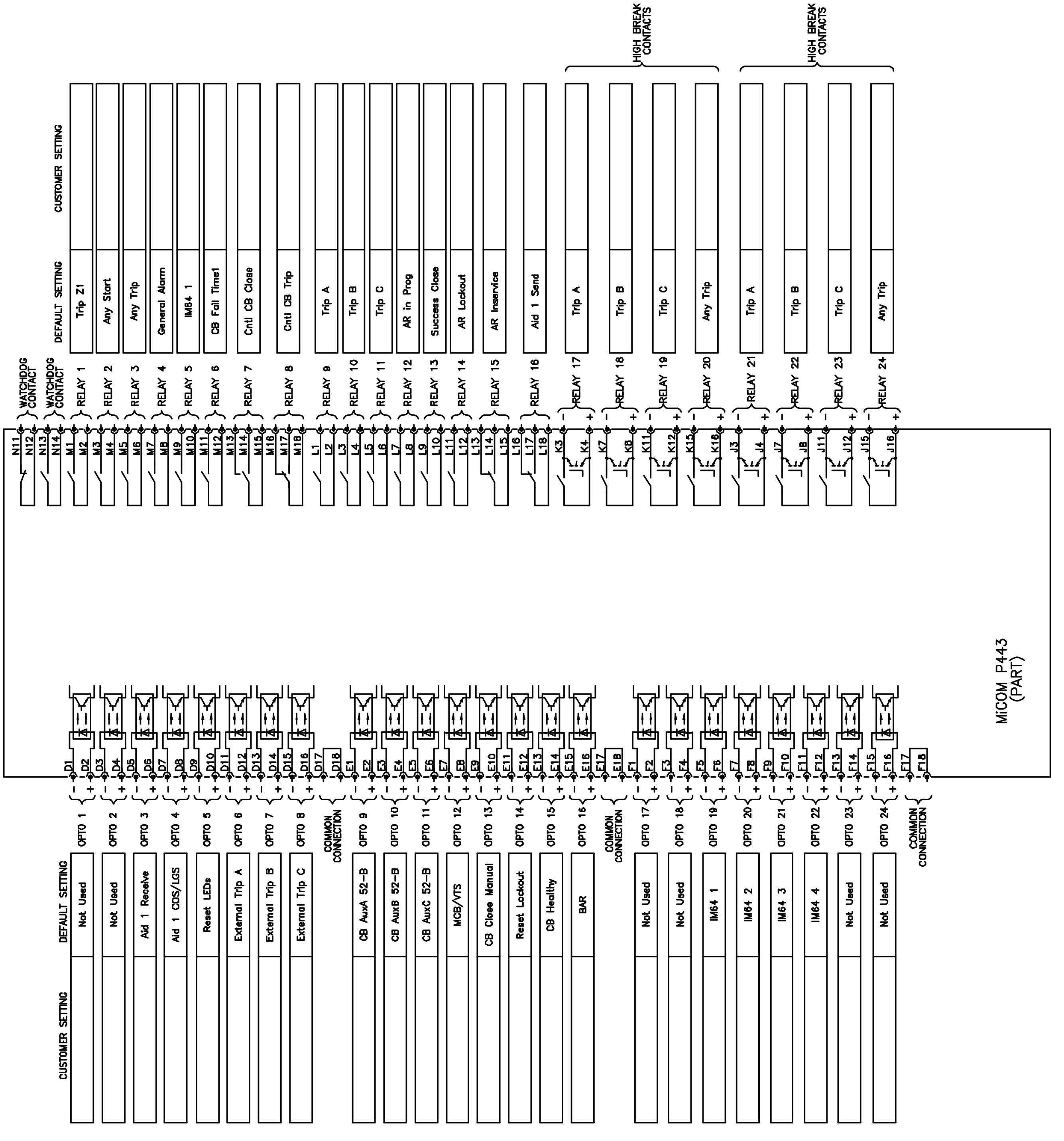
Figure 10 - P443 C external connections (80TE) - inputs/outputs default mapping - high break relay outputs 16 I/P & 20 O/P


MiCOM P443 (PART)
HIGH BREAK CONTACTS
RELAY 17
RELAY 18
RELAY 19
RELAY 20
RELAY 21
RELAY 22
RELAY 23
RELAY 24
COMMS NOTE 5.
AC OR DC AUX SUPPLY
Vx
48V DC FIELD VOLTAGE OUT
EIA485/ KBUS PORT
CASE EARTH
SEE DRAWING 10Px4001.
N16 SCN
* POWER SUPPLY VERSION 24-48V (NOMINAL) D.C. ONLY
WATCHDOG CONTACT
RELAY 1
RELAY 2
RELAY 3
RELAY 4
RELAY 5
RELAY 6
RELAY 7
RELAY 8
RELAY 9
RELAY 10
RELAY 11
RELAY 12
RELAY 13
RELAY 14
RELAY 15
RELAY 16
TX1
RX1
TX2
RX2
FIBRE OPTIC COMMUNICATION INTERMICOM 64
OPTO 1
OPTO 2
OPTO 3
OPTO 4
OPTO 5
OPTO 6
OPTO 7
OPTO 8
COMMON CONNECTION
OPTO 9
OPTO 10
OPTO 11
OPTO 12
OPTO 13
OPTO 14
OPTO 15
OPTO 16
OPTO 17
OPTO 18
OPTO 19
OPTO 20
OPTO 21
OPTO 22
OPTO 23
OPTO 24
PHASE ROTATION NOTE 7
DIRECTION OF FORWARD CURRENT FLOW (NOTE 6)
NOTE 4.
NOTE 8.
IN SENSITIVE
SEE NOTE 2.
PARALLEL LINE PROTECTION
DISTANCE PROTECTION (24 I/P &32 O/P)
V BUSBAR (SEE NOTE 3.)
NOTES 1. (a) C.T. SHORTING LINKS
(b) PIN TERMINAL (P.C.B. TYPE)
2. IM INPUT IS FOR OPTIONAL MUTUAL COMPENSATION.
3. V BUSBAR ONLY REQUIRED IF CHECK SYNCHRONISM FUNCTION ENABLED.
4. C.T. CONNECTIONS ARE SHOWN 1A CONNECTED AND ARE TYPICAL ONLY.
5. FOR COMMS OPTIONS SEE DRAWING 10PX4001
6. WITH C.T. POLARITY SETTING 'STANDARD'.
7. REVERSE PHASE ROTATION IS ALSO SUPPORTED.
8. USED FOR SEF PROTECTION. IN SENSITIVE SHOULD BE DRIVEN FROM A CORE BALANCE CT WHEN SENSITIVE SETTINGS ARE USED.

Based on 10P44305 Sheet 1 Issue B

P0321ENa

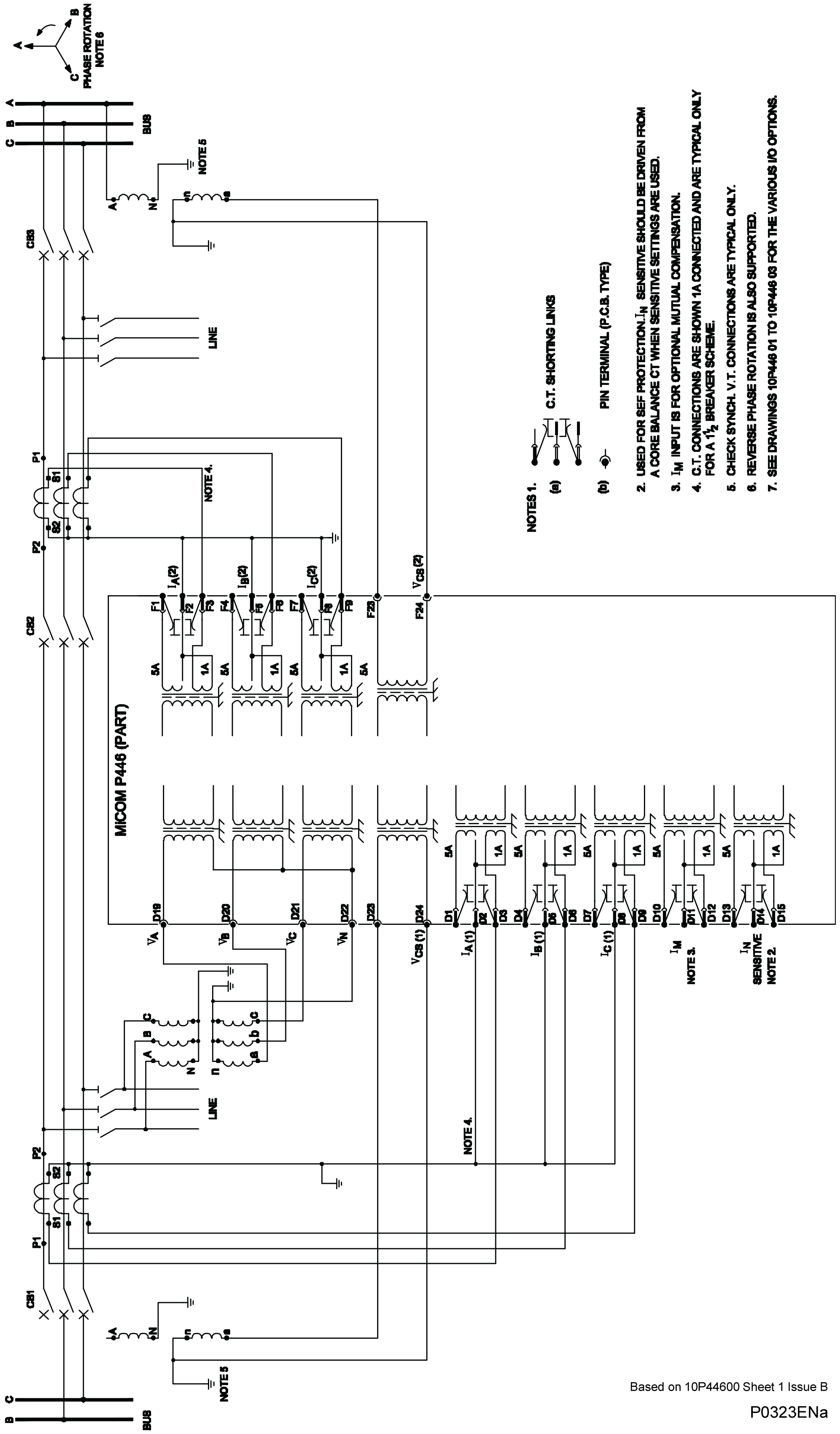
Figure 11 - P443 D external connections (80TE) - high break relay outputs 24 I/P & 24 O/P


HIGH BREAK CONTACTS
HIGH BREAK CONTACTS
CUSTOMER SETTING
DEFAULT SETTING
Trip Z1
Any Start
Any Trip
General Alarm
IM64 1
CB Fail Time1
Cntl CB Close
Cntl CB Trip
Trip A
Trip B
Trip C
AR in Prog
Success Close
AR Lockout
AR Inservice
Aid 1 Send
Trip A
Trip B
Trip C
Any Trip
Trip A
Trip B
Trip C
Any Trip
WATCHDOG CONTACT
WATCHDOG CONTACT
RELAY 1
RELAY 2
RELAY 3
RELAY 4
RELAY 5
RELAY 6
RELAY 7
RELAY 8
RELAY 9
RELAY 10
RELAY 11
RELAY 12
RELAY 13
RELAY 14
RELAY 15
RELAY 16
RELAY 17
RELAY 18
RELAY 19
RELAY 20
RELAY 21
RELAY 22
RELAY 23
RELAY 24
N11 N12 N13 N14
M1 M2 M3 M4 M5 M6 M7 M8 M9 M10 M11 M12 M13 M14 M15 M16 M17 M18
L1 L2 L3 L4 L5 L6 L7 L8 L9 L10 L11 L12 L13 L14 L15 L16 L17 L18
K3 K4 K7 K8 K11 K12 K15 K16
J3 J4 J7 J8 J11 J12 J15 J16
MiCOM P443 (PART)
D1 D2 D3 D4 D5 D6 D7 D8 D9 D10 D11 D12 D13 D14 D15 D16 D17 D18
E1 E2 E3 E4 E5 E6 E7 E8 E9 E10 E11 E12 E13 E14 E15 E16 E17 E18
F1 F2 F3 F4 F5 F6 F7 F8 F9 F10 F11 F12 F13 F14 F15 F16 F17 F18
OPTO 1
OPTO 2
OPTO 3
OPTO 4
OPTO 5
OPTO 6
OPTO 7
OPTO 8
COMMON CONNECTION
OPTO 9
OPTO 10
OPTO 11
OPTO 12
OPTO 13
OPTO 14
OPTO 15
OPTO 16
COMMON CONNECTION
OPTO 17
OPTO 18
OPTO 19
OPTO 20
OPTO 21
OPTO 22
OPTO 23
OPTO 24
COMMON CONNECTION
DEFAULT SETTING
Not Used
Not Used
Aid 1 Receive
Aid 1 COS/LGS
Reset LEDs
External Trip A
External Trip B
External Trip C
CB AuxA 52-B
CB AuxB 52-B
CB AuxC 52-B
MCB/VTS
CB Close Manual
Reset Lockout
CB Healthy
BAR
Not Used
Not Used
IM64 1
IM64 2
IM64 3
IM64 4
Not Used
Not Used
CUSTOMER SETTING

Based on 10P44305 Sheet 3 Issue B

P0322ENa

Figure 12 - P443 D external connections (80TE) - inputs/outputs default mapping - high break relay outputs 24 I/P & 24 O/P


A
B
C
PHASE ROTATION
NOTE 6
BUS
CB3
CB2
CB1
NOTE 5
LINE
P1
P2
S1
S2
NOTE 4.
MiCOM P446 (PART)
$I_A(2)$
$I_B(2)$
$I_C(2)$
$V_{CS}(2)$
F1
F2
F3
F4
F5
F6
F7
F8
F9
F23
F24
5A
1A
V_A
V_B
V_C
V_N
$V_{CS}(1)$
$I_A(1)$
$I_B(1)$
$I_C(1)$
I_M
NOTE 3.
I_N SENSITIVE
NOTE 2.
D1
D2
D3
D4
D5
D6
D7
D8
D9
D10
D11
D12
D13
D14
D15
D19
D20
D21
D22
D23
D24
N
n
a
b
c

NOTES 1. (a) C.T. SHORTING LINKS

(b) PIN TERMINAL (P.C.B. TYPE)

2. USED FOR SEF PROTECTION. I_N SENSITIVE SHOULD BE DRIVEN FROM A CORE BALANCE CT WHEN SENSITIVE SETTINGS ARE USED.

3. I_M INPUT IS FOR OPTIONAL MUTUAL COMPENSATION.

4. C.T. CONNECTIONS ARE SHOWN 1A CONNECTED AND ARE TYPICAL ONLY FOR A 1½ BREAKER SCHEME.

5. CHECK SYNCH. V.T. CONNECTIONS ARE TYPICAL ONLY.

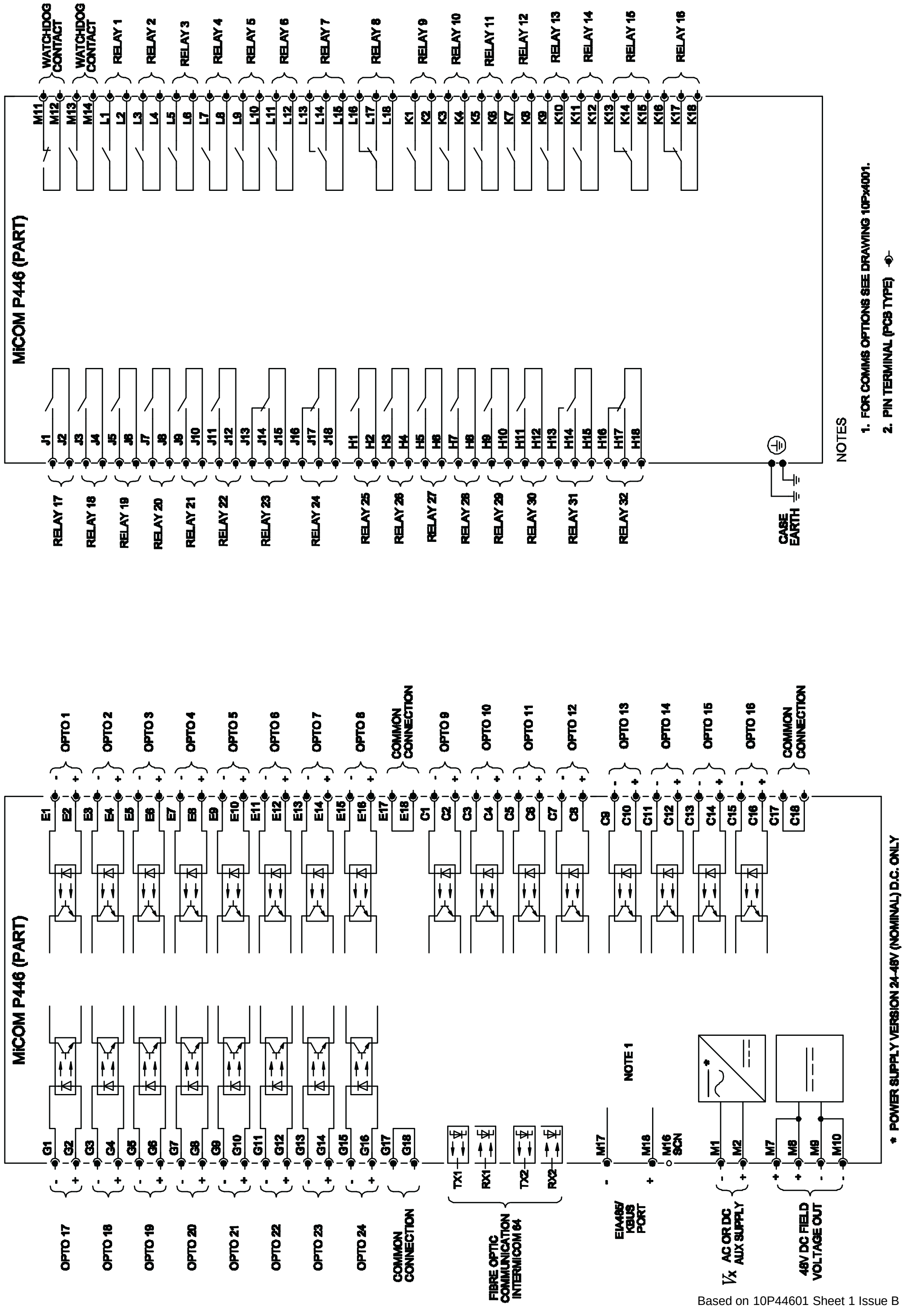
6. REVERSE PHASE ROTATION IS ALSO SUPPORTED.

7. SEE DRAWINGS 10P446 01 TO 10P446 03 FOR THE VARIOUS I/O OPTIONS.

Based on 10P44600 Sheet 1 Issue B

P0323ENa

Figure 13 - P446 Common external connections (80TE) - power systems connection


MiCOM P446 (PART)
WATCHDOG CONTACT
RELAY 1
RELAY 2
RELAY 3
RELAY 4
RELAY 5
RELAY 6
RELAY 7
RELAY 8
RELAY 9
RELAY 10
RELAY 11
RELAY 12
RELAY 13
RELAY 14
RELAY 15
RELAY 16
M11 M12 M13 M14 L1 L2 L3 L4 L5 L6 L7 L8 L9 L10 L11 L12 L13 L14 L15 L16 L17 L18
K1 K2 K3 K4 K5 K6 K7 K8 K9 K10 K11 K12 K13 K14 K15 K16 K17 K18
J1 J2 J3 J4 J5 J6 J7 J8 J9 J10 J11 J12 J13 J14 J15 J16 J17 J18
H1 H2 H3 H4 H5 H6 H7 H8 H9 H10 H11 H12 H13 H14 H15 H16 H17 H18
RELAY 17
RELAY 18
RELAY 19
RELAY 20
RELAY 21
RELAY 22
RELAY 23
RELAY 24
RELAY 25
RELAY 26
RELAY 27
RELAY 28
RELAY 29
RELAY 30
RELAY 31
RELAY 32
CASE EARTH
NOTES
1. FOR COMMS OPTIONS SEE DRAWING 10Px4001.
2. PIN TERMINAL (PCB TYPE)
OPTO 1
OPTO 2
OPTO 3
OPTO 4
OPTO 5
OPTO 6
OPTO 7
OPTO 8
COMMON CONNECTION
OPTO 9
OPTO 10
OPTO 11
OPTO 12
OPTO 13
OPTO 14
OPTO 15
OPTO 16
COMMON CONNECTION
E1 E2 E3 E4 E5 E6 E7 E8 E9 E10 E11 E12 E13 E14 E15 E16 E17 E18
C1 C2 C3 C4 C5 C6 C7 C8 C9 C10 C11 C12 C13 C14 C15 C16 C17 C18
MiCOM P446 (PART)
NOTE 1
* POWER SUPPLY VERSION 24-48V (NOMINAL) D.C. ONLY
G1 G2 G3 G4 G5 G6 G7 G8 G9 G10 G11 G12 G13 G14 G15 G16 G17 G18
TX1 RX1 TX2 RX2
M17 M18 M16 SCN
M1 M2 M7 M8 M9 M10
OPTO 17
OPTO 18
OPTO 19
OPTO 20
OPTO 21
OPTO 22
OPTO 23
OPTO 24
COMMON CONNECTION
FIBRE OPTIC COMMUNICATION INTERMICOM 64
EIA485/ KBUS PORT
Vx AC OR DC AUX SUPPLY
48V DC FIELD VOLTAGE OUT

Based on 10P44601 Sheet 1 Issue B

P0324ENa

Figure 14 - P446 B external connections - 24 I/P & 32 O/P

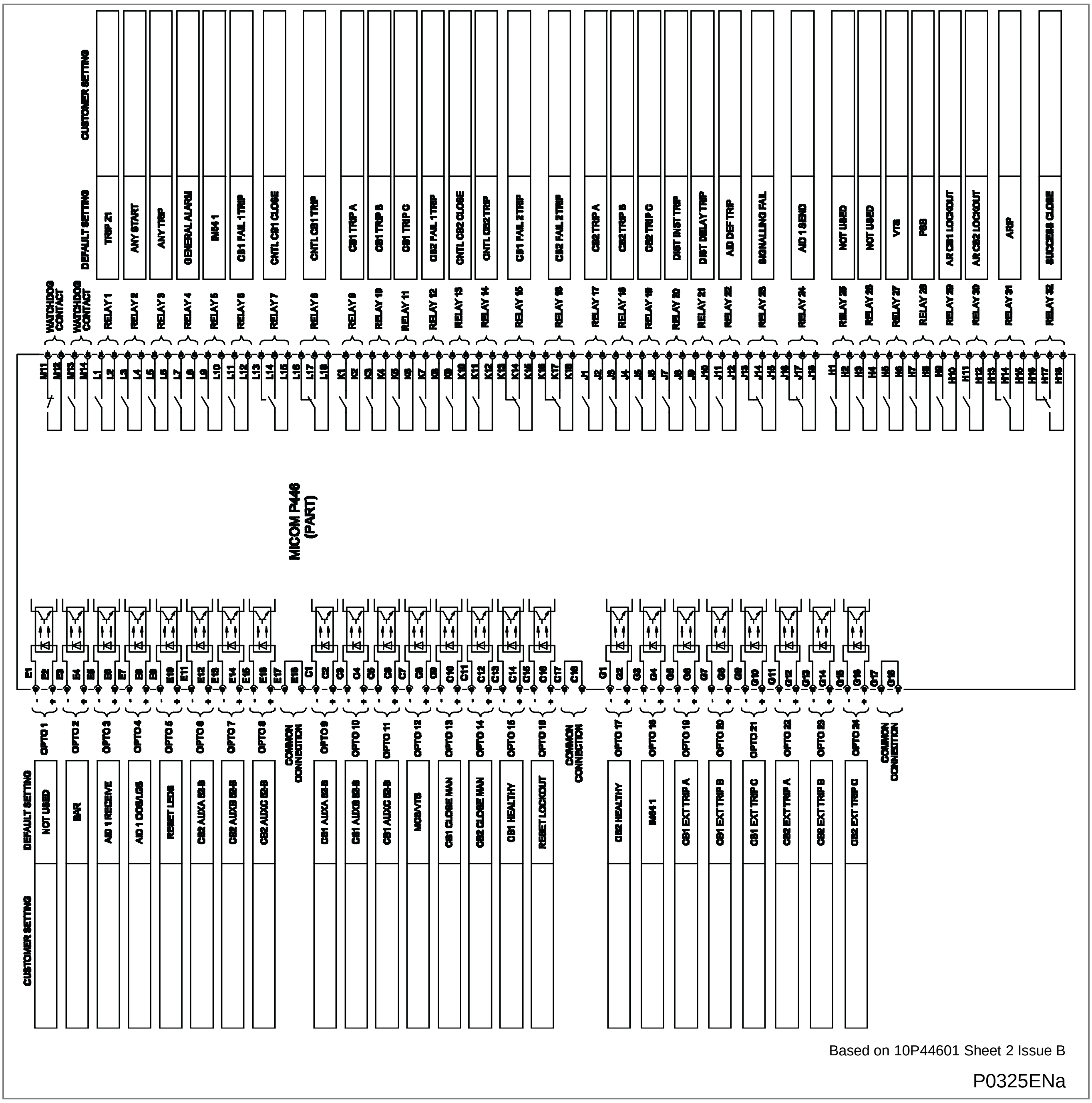
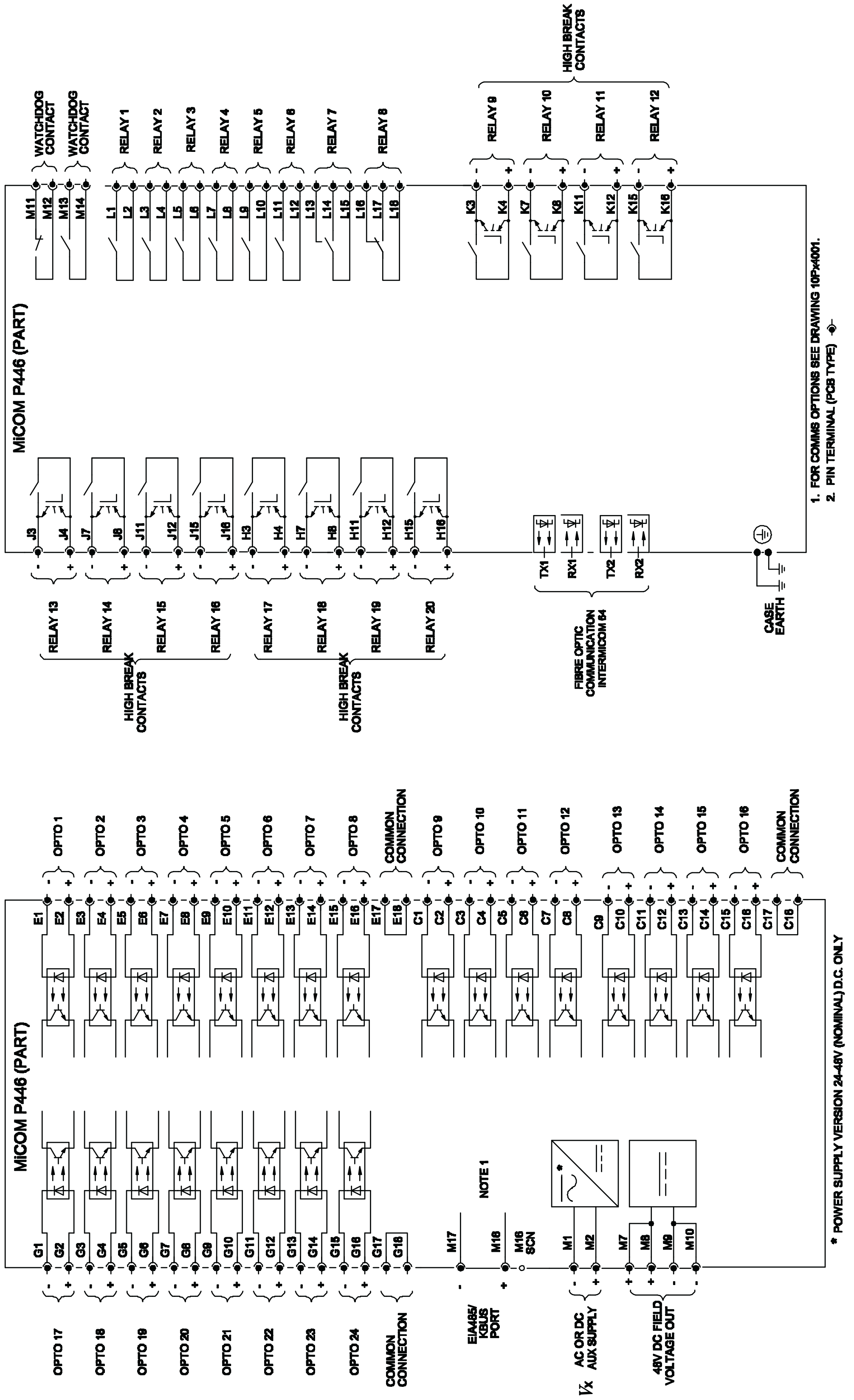

CUSTOMER SETTING
DEFAULT SETTING
MICOM P446 (PART)
WATCHDOG CONTACT M11 M12
WATCHDOG CONTACT M13 M14
RELAY 1 L1 L2 TRIP Z1
RELAY 2 L3 L4 ANY START
RELAY 3 L5 L6 ANY TRIP
RELAY 4 L7 L8 GENERAL ALARM
RELAY 5 L9 L10 IM64 1
RELAY 6 L11 L12 CB1 FAIL 1 TRIP
RELAY 7 L13 L14 L15 CNTL CB1 CLOSE
RELAY 8 L16 L17 L18 CNTL CB1 TRIP
RELAY 9 K1 K2 CB1 TRIP A
RELAY 10 K3 K4 CB1 TRIP B
RELAY 11 K5 K6 CB1 TRIP C
RELAY 12 K7 K8 CB2 FAIL 1 TRIP
RELAY 13 K9 K10 CNTL CB2 CLOSE
RELAY 14 K11 K12 CNTL CB2 TRIP
RELAY 15 K13 K14 K15 CB1 FAIL 2 TRIP
RELAY 16 K16 K17 K18 CB2 FAIL 2 TRIP
RELAY 17 J1 J2 CB2 TRIP A
RELAY 18 J3 J4 CB2 TRIP B
RELAY 19 J5 J6 CB2 TRIP C
RELAY 20 J7 J8 DIST INST TRIP
RELAY 21 J9 J10 DIST DELAY TRIP
RELAY 22 J11 J12 AID DEF TRIP
RELAY 23 J13 J14 J15 SIGNALLING FAIL
RELAY 24 J16 J17 J18 AID 1 SEND
RELAY 25 H1 H2 NOT USED
RELAY 26 H3 H4 NOT USED
RELAY 27 H5 H6 VTS
RELAY 28 H7 H8 PSB
RELAY 29 H9 H10 AR CB1 LOCKOUT
RELAY 30 H11 H12 AR CB2 LOCKOUT
RELAY 31 H13 H14 H15 ARIP
RELAY 32 H16 H17 H18 SUCCESS CLOSE
OPTO 1 E1 E2 NOT USED
OPTO 2 E3 E4 BAR
OPTO 3 E5 E6 AID 1 RECEIVE
OPTO 4 E7 E8 AID 1 COS/LGS
OPTO 5 E9 E10 RESET LEDS
OPTO 6 E11 E12 CB2 AUXA 52-B
OPTO 7 E13 E14 CB2 AUXB 52-B
OPTO 8 E15 E16 CB2 AUXC 52-B
COMMON CONNECTION E17 E18
OPTO 9 C1 C2 CB1 AUXA 52-B
OPTO 10 C3 C4 CB1 AUXB 52-B
OPTO 11 C5 C6 CB1 AUXC 52-B
OPTO 12 C7 C8 MCB/VTS
OPTO 13 C9 C10 CB1 CLOSE MAN
OPTO 14 C11 C12 CB2 CLOSE MAN
OPTO 15 C13 C14 CB1 HEALTHY
OPTO 16 C15 C16 RESET LOCKOUT
COMMON CONNECTION C17 C18
OPTO 17 G1 G2 CB2 HEALTHY
OPTO 18 G3 G4 IM64 1
OPTO 19 G5 G6 CB1 EXT TRIP A
OPTO 20 G7 G8 CB1 EXT TRIP B
OPTO 21 G9 G10 CB1 EXT TRIP C
OPTO 22 G11 G12 CB2 EXT TRIP A
OPTO 23 G13 G14 CB2 EXT TRIP B
OPTO 24 G15 G16 CB2 EXT TRIP C
COMMON CONNECTION G17 G18
Based on 10P44601 Sheet 2 Issue B
P0325ENa

Figure 15 - P446 B external connections - 24 I/P & 32 O/P


MiCOM P446 (PART)
WATCHDOG CONTACT
WATCHDOG CONTACT
RELAY 1
RELAY 2
RELAY 3
RELAY 4
RELAY 5
RELAY 6
RELAY 7
RELAY 8
RELAY 9
RELAY 10
RELAY 11
RELAY 12
HIGH BREAK CONTACTS
M11
M12
M13
M14
L1
L2
L3
L4
L5
L6
L7
L8
L9
L10
L11
L12
L13
L14
L15
L16
L17
L18
K3
K4
K7
K8
K11
K12
K15
K16
J3
J4
J7
J8
J11
J12
J15
J16
H3
H4
H7
H8
H11
H12
H15
H16
RELAY 13
RELAY 14
RELAY 15
RELAY 16
RELAY 17
RELAY 18
RELAY 19
RELAY 20
HIGH BREAK CONTACTS
HIGH BREAK CONTACTS
TX1
RX1
TX2
RX2
FIBRE OPTIC COMMUNICATION INTERMICOM 64
CASE EARTH
MiCOM P446 (PART)
OPTO 1
OPTO 2
OPTO 3
OPTO 4
OPTO 5
OPTO 6
OPTO 7
OPTO 8
COMMON CONNECTION
OPTO 9
OPTO 10
OPTO 11
OPTO 12
OPTO 13
OPTO 14
OPTO 15
OPTO 16
COMMON CONNECTION
E1
E2
E3
E4
E5
E6
E7
E8
E9
E10
E11
E12
E13
E14
E15
E16
E17
E18
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
C11
C12
C13
C14
C15
C16
C17
C18
G1
G2
G3
G4
G5
G6
G7
G8
G9
G10
G11
G12
G13
G14
G15
G16
G17
G18
M17
M18
M16 SCN
M1
M2
M7
M8
M9
M10
NOTE 1
OPTO 17
OPTO 18
OPTO 19
OPTO 20
OPTO 21
OPTO 22
OPTO 23
OPTO 24
COMMON CONNECTION
EIA485/ KBUS PORT
AC OR DC AUX SUPPLY
Vx
48V DC FIELD VOLTAGE OUT
-
+
*

1. FOR COMMS OPTIONS SEE DRAWING 10Px4001.
2. PIN TERMINAL (PCB TYPE)

* POWER SUPPLY VERSION 24-48V (NOMINAL) D.C. ONLY

Based on 10P44602 Sheet 1 Issue B

P0326ENa

Figure 16 - P446 C external connections - 24 I/P, 8 standard relay O/P & 12 high-break O/P

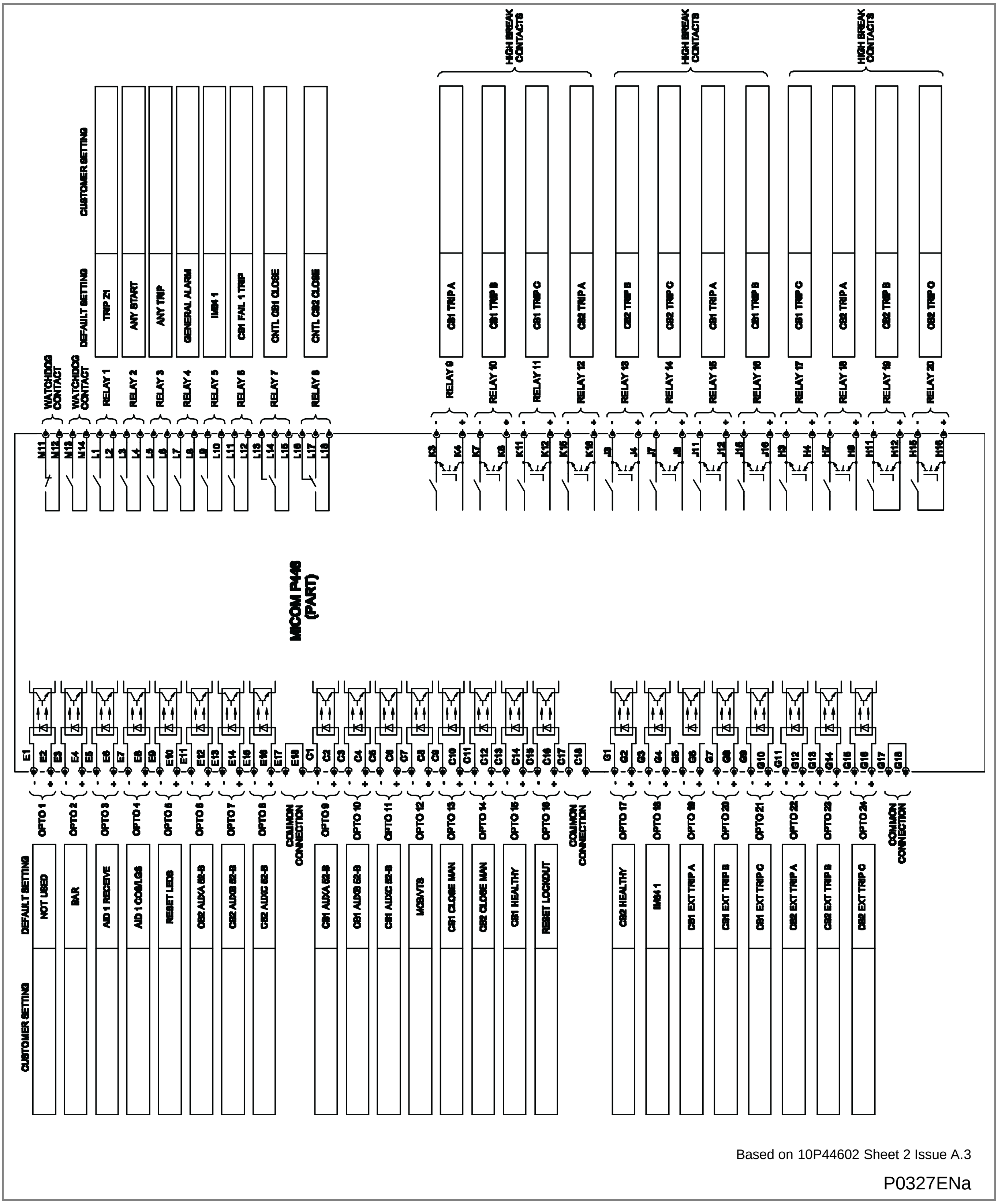
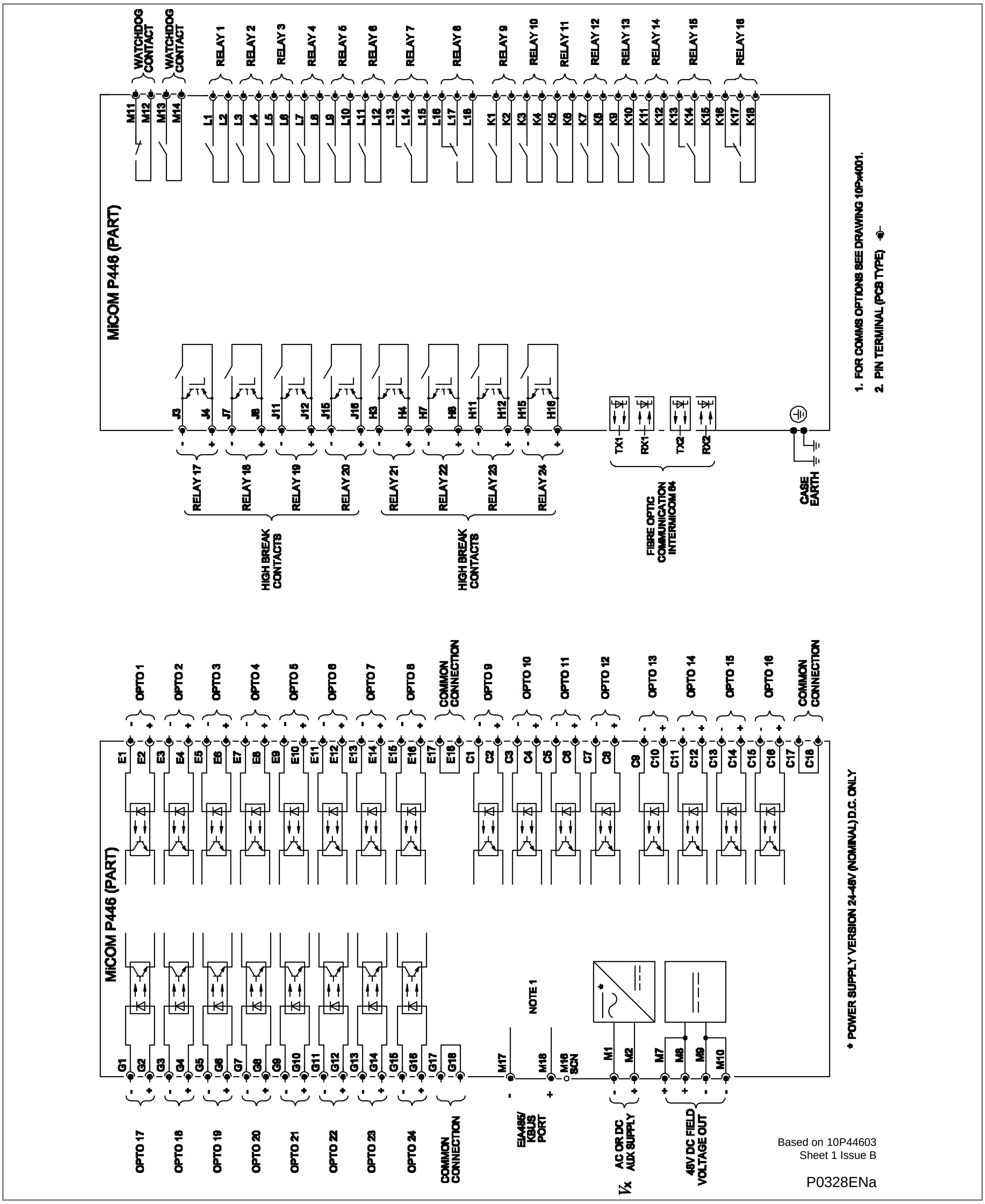

MiCOM P446 (PART)
CUSTOMER SETTING
DEFAULT SETTING
WATCHDOG CONTACT M11 M12
WATCHDOG CONTACT M13 M14
RELAY 1 L1 L2 TRIP Z1
RELAY 2 L3 L4 ANY START
RELAY 3 L5 L6 ANY TRIP
RELAY 4 L7 L8 GENERAL ALARM
RELAY 5 L9 L10 IM64 1
RELAY 6 L11 L12 CB1 FAIL 1 TRIP
RELAY 7 L13 L14 L15 CNTL CB1 CLOSE
RELAY 8 L16 L17 L18 CNTL CB2 CLOSE
HIGH BREAK CONTACTS
RELAY 9 K3 K4 CB1 TRIP A
RELAY 10 K7 K8 CB1 TRIP B
RELAY 11 K11 K12 CB1 TRIP C
RELAY 12 K15 K16 CB2 TRIP A
HIGH BREAK CONTACTS
RELAY 13 J3 J4 CB2 TRIP B
RELAY 14 J7 J8 CB2 TRIP C
RELAY 15 J11 J12 CB1 TRIP A
RELAY 16 J15 J16 CB1 TRIP B
HIGH BREAK CONTACTS
RELAY 17 H3 H4 CB1 TRIP C
RELAY 18 H7 H8 CB2 TRIP A
RELAY 19 H11 H12 CB2 TRIP B
RELAY 20 H15 H16 CB2 TRIP C
E1
OPTO 1 E2 E3 NOT USED
OPTO 2 E4 E5 BAR
OPTO 3 E6 E7 AID 1 RECEIVE
OPTO 4 E8 E9 AID 1 COS/LGS
OPTO 5 E10 E11 RESET LEDS
OPTO 6 E12 E13 CB2 AUXA 52-B
OPTO 7 E14 E15 CB2 AUXB 52-B
OPTO 8 E16 E17 CB2 AUXC 52-B
COMMON CONNECTION E18
C1
OPTO 9 C2 C3 CB1 AUXA 52-B
OPTO 10 C4 C5 CB1 AUXB 52-B
OPTO 11 C6 C7 CB1 AUXC 52-B
OPTO 12 C8 C9 MCB/VTS
OPTO 13 C10 C11 CB1 CLOSE MAN
OPTO 14 C12 C13 CB2 CLOSE MAN
OPTO 15 C14 C15 CB1 HEALTHY
OPTO 16 C16 C17 RESET LOCKOUT
COMMON CONNECTION C18
G1
OPTO 17 G2 G3 CB2 HEALTHY
OPTO 18 G4 G5 IM64 1
OPTO 19 G6 G7 CB1 EXT TRIP A
OPTO 20 G8 G9 CB1 EXT TRIP B
OPTO 21 G10 G11 CB1 EXT TRIP C
OPTO 22 G12 G13 CB2 EXT TRIP A
OPTO 23 G14 G15 CB2 EXT TRIP B
OPTO 24 G16 G17 CB2 EXT TRIP C
COMMON CONNECTION G18
- +
Based on 10P44602 Sheet 2 Issue A.3
P0327ENa

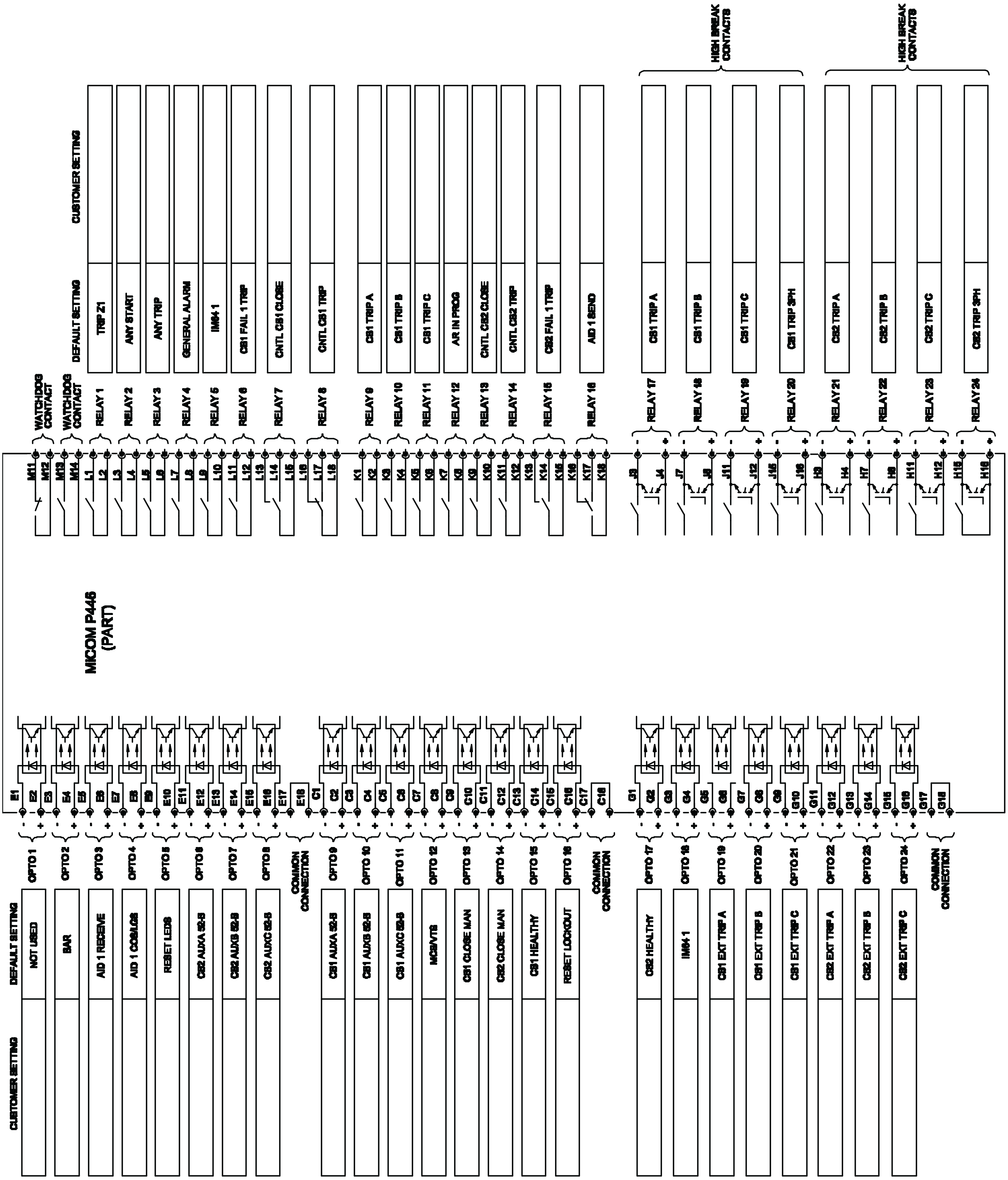
Figure 17 - P446 C external connections - 24 I/P, 8 standard relay O/P & 12 high-break O/P


MiCOM P446 (PART)
WATCHDOG CONTACT
WATCHDOG CONTACT
M11
M12
M13
M14
RELAY 1
RELAY 2
RELAY 3
RELAY 4
RELAY 5
RELAY 6
RELAY 7
RELAY 8
RELAY 9
RELAY 10
RELAY 11
RELAY 12
RELAY 13
RELAY 14
RELAY 15
RELAY 16
L1
L2
L3
L4
L5
L6
L7
L8
L9
L10
L11
L12
L13
L14
L15
L16
L17
L18
K1
K2
K3
K4
K5
K6
K7
K8
K9
K10
K11
K12
K13
K14
K15
K16
K17
K18
J3
J4
J7
J8
J11
J12
J15
J16
H3
H4
H7
H8
H11
H12
H15
H16
RELAY 17
RELAY 18
RELAY 19
RELAY 20
RELAY 21
RELAY 22
RELAY 23
RELAY 24
HIGH BREAK CONTACTS
HIGH BREAK CONTACTS
TX1
RX1
TX2
RX2
FIBRE OPTIC COMMUNICATION INTERMICOM 64
CASE EARTH
1. FOR COMMS OPTIONS SEE DRAWING 10Px4001.
2. PIN TERMINAL (PCB TYPE)
MiCOM P446 (PART)
OPTO 1
OPTO 2
OPTO 3
OPTO 4
OPTO 5
OPTO 6
OPTO 7
OPTO 8
COMMON CONNECTION
OPTO 9
OPTO 10
OPTO 11
OPTO 12
OPTO 13
OPTO 14
OPTO 15
OPTO 16
COMMON CONNECTION
E1
E2
E3
E4
E5
E6
E7
E8
E9
E10
E11
E12
E13
E14
E15
E16
E17
E18
C1
C2
C3
C4
C5
C6
C7
C8
C9
C10
C11
C12
C13
C14
C15
C16
C17
C18
G1
G2
G3
G4
G5
G6
G7
G8
G9
G10
G11
G12
G13
G14
G15
G16
G17
G18
OPTO 17
OPTO 18
OPTO 19
OPTO 20
OPTO 21
OPTO 22
OPTO 23
OPTO 24
COMMON CONNECTION
NOTE 1
M17
M18
M16 SCN
EIA485/ KBUS PORT
M1
M2
AC OR DC AUX SUPPLY
Vx
M7
M8
M9
M10
48V DC FIELD VOLTAGE OUT
* POWER SUPPLY VERSION 24-48V (NOMINAL) D.C. ONLY

Based on 10P44603
Sheet 1 Issue B

P0328ENa

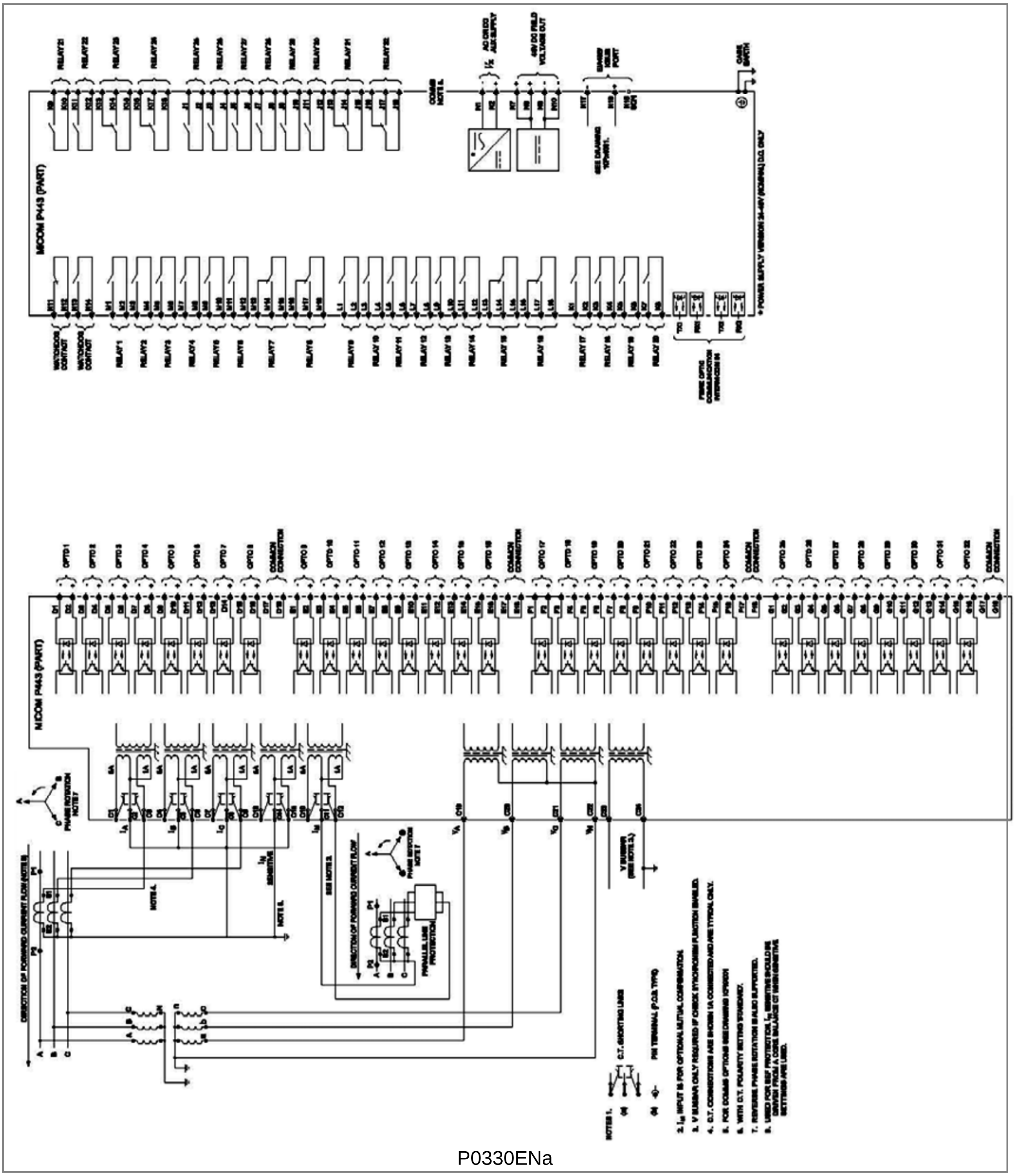
Figure 18 - P446 D external connections - 24 I/P, 16 standard relay O/P & 8 high-break O/P


MICOM P446
(PART)
CUSTOMER SETTING
DEFAULT SETTING
HIGH BREAK CONTACTS
WATCHDOG CONTACT
M11 M12 M13 M14
RELAY 1 TRIP Z1 L1 L2
RELAY 2 ANY START L3 L4
RELAY 3 ANY TRIP L5 L6
RELAY 4 GENERAL ALARM L7 L8
RELAY 5 IM64 1 L9 L10
RELAY 6 CB1 FAIL 1 TRIP L11 L12
RELAY 7 CNTL CB1 CLOSE L13 L14 L15
RELAY 8 CNTL CB1 TRIP L16 L17 L18
RELAY 9 CB1 TRIP A K1 K2
RELAY 10 CB1 TRIP B K3 K4
RELAY 11 CB1 TRIP C K5 K6
RELAY 12 AR IN PROG K7 K8
RELAY 13 CNTL CB2 CLOSE K9 K10
RELAY 14 CNTL CB2 TRIP K11 K12
RELAY 15 CB2 FAIL 1 TRIP K13 K14 K15
RELAY 16 AID 1 SEND K16 K17 K18
RELAY 17 CB1 TRIP A J3 J4
RELAY 18 CB1 TRIP B J7 J8
RELAY 19 CB1 TRIP C J11 J12
RELAY 20 CB1 TRIP 3PH J15 J16
RELAY 21 CB2 TRIP A H3 H4
RELAY 22 CB2 TRIP B H7 H8
RELAY 23 CB2 TRIP C H11 H12
RELAY 24 CB2 TRIP 3PH H15 H16
OPTO 1 NOT USED E1 E2
OPTO 2 BAR E3 E4
OPTO 3 AID 1 RECEIVE E5 E6
OPTO 4 AID 1 COS/LGS E7 E8
OPTO 5 RESET LEDS E9 E10
OPTO 6 CB2 AUXA 52-B E11 E12
OPTO 7 CB2 AUXB 52-B E13 E14
OPTO 8 CB2 AUXC 52-B E15 E16
COMMON CONNECTION E17 E18
OPTO 9 CB1 AUXA 52-B C1 C2
OPTO 10 CB1 AUXB 52-B C3 C4
OPTO 11 CB1 AUXC 52-B C5 C6
OPTO 12 MCB/VTS C7 C8
OPTO 13 CB1 CLOSE MAN C9 C10
OPTO 14 CB2 CLOSE MAN C11 C12
OPTO 15 CB1 HEALTHY C13 C14
OPTO 16 RESET LOCKOUT C15 C16
COMMON CONNECTION C17 C18
OPTO 17 CB2 HEALTHY G1 G2
OPTO 18 IM64 1 G3 G4
OPTO 19 CB1 EXT TRIP A G5 G6
OPTO 20 CB1 EXT TRIP B G7 G8
OPTO 21 CB1 EXT TRIP C G9 G10
OPTO 22 CB2 EXT TRIP A G11 G12
OPTO 23 CB2 EXT TRIP B G13 G14
OPTO 24 CB2 EXT TRIP C G15 G16
COMMON CONNECTION G17 G18
- +

Based on 10P44603
Sheet 2 Issue B

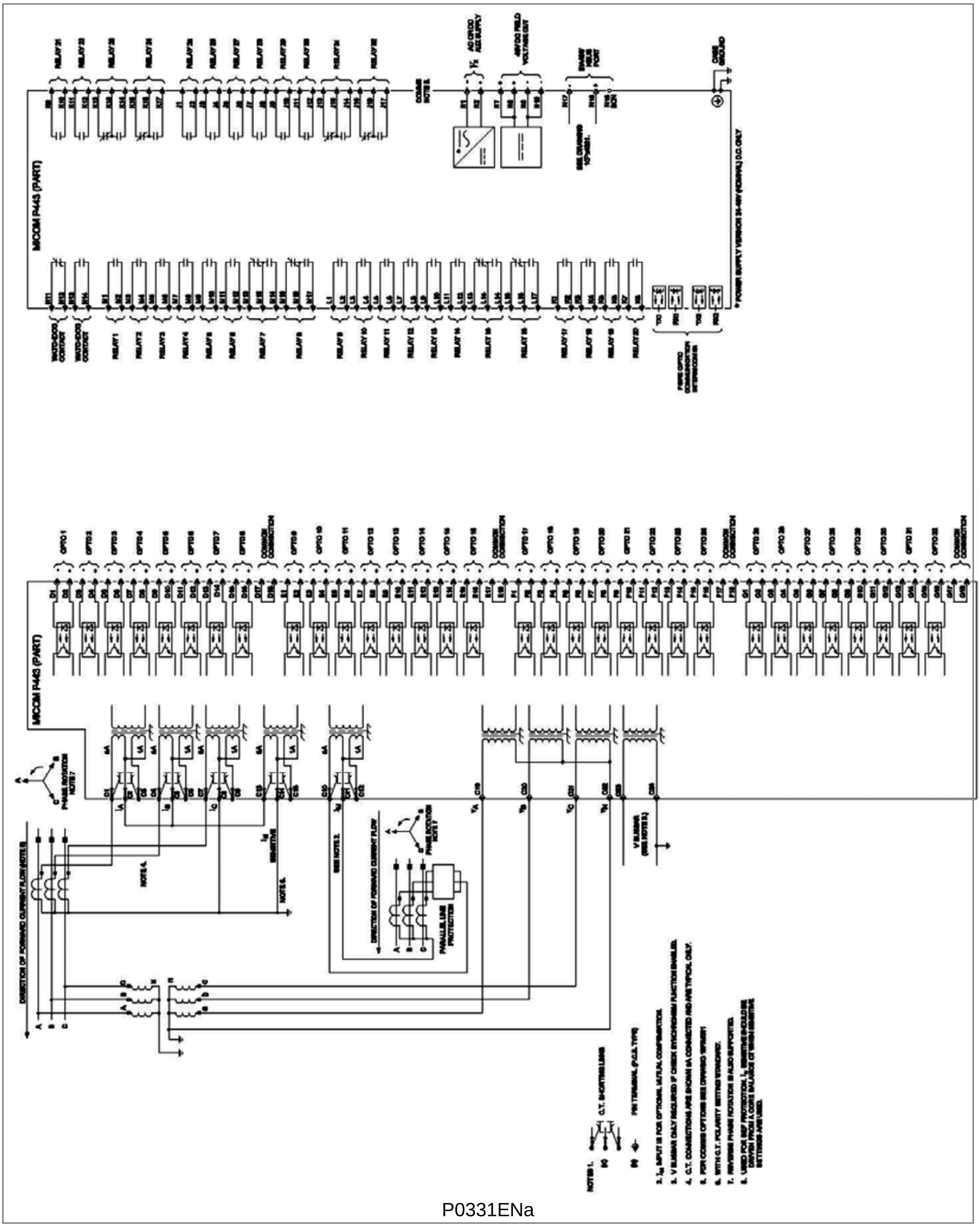
P0329ENa

Figure 19 - P446 D external connections - 24 I/P, 16 standard relay O/P& 8 high-break O/P



P0330ENa

Figure 20 - P446 D external connections - 32 I/P & 32 O/P



P0331ENa

Figure 21 - P446 D external connections - 32 I/P & 32 O/P

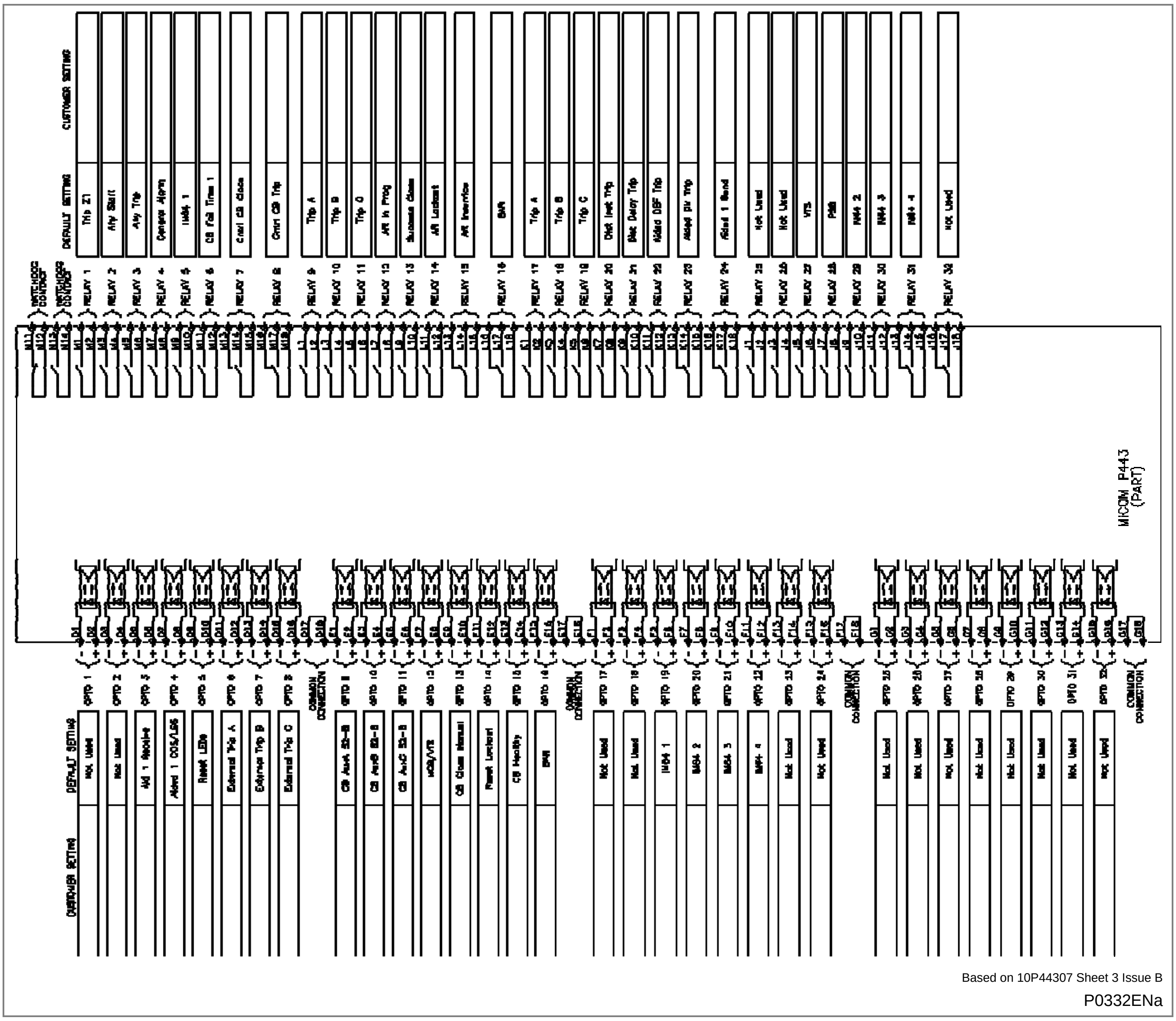
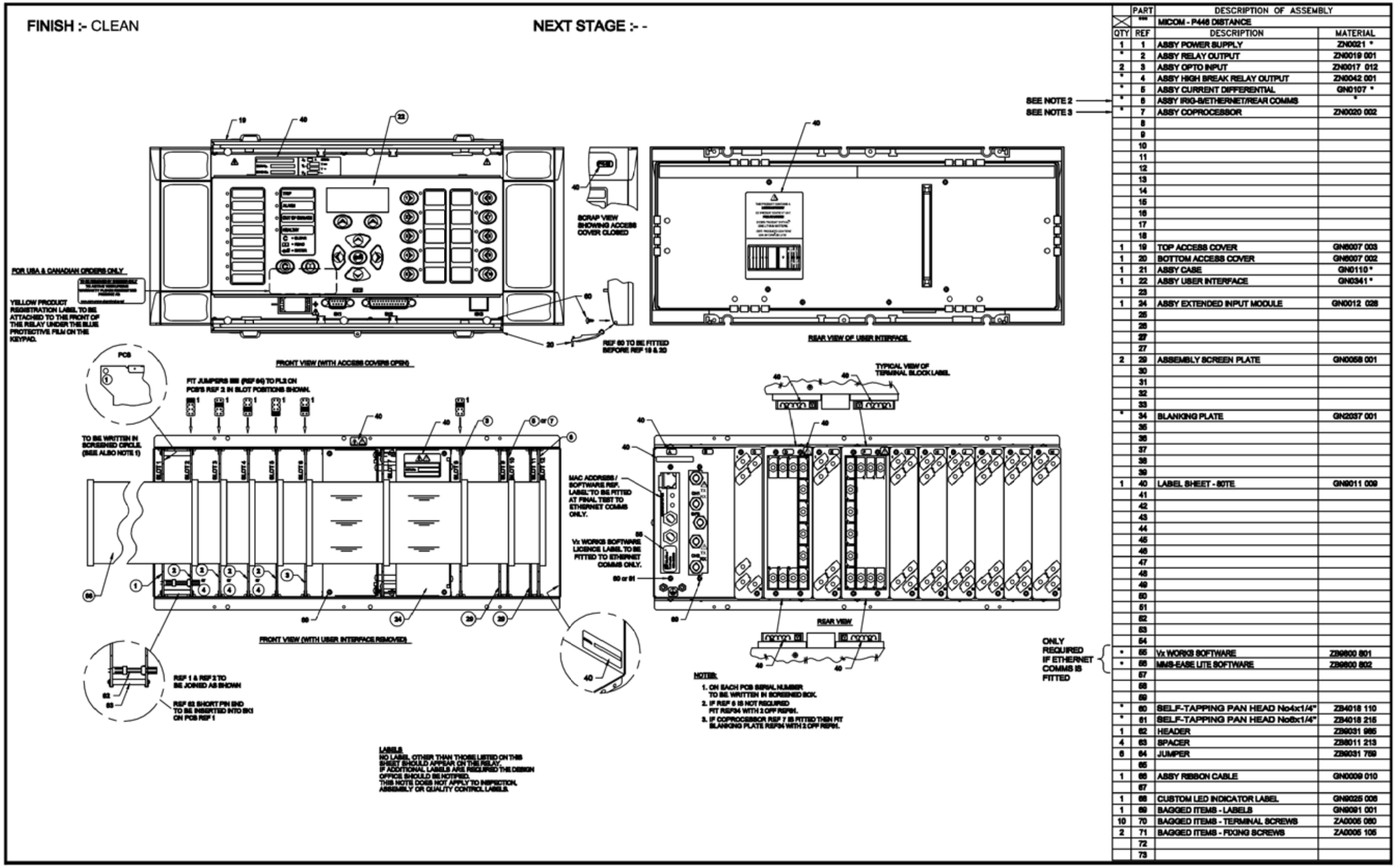

CUSTOMER SETTING
DEFAULT SETTING
Trip Z1
Any Start
Any Trip
General Alarm
IM64 1
CB Fail Time 1
Cntrl CB Close
Cntrl CB Trip
Trip A
Trip B
Trip C
AR In Prog
Success Close
AR Lockout
AR Inservice
BAR
Trip A
Trip B
Trip C
Dist Inst Trip
Dist Delay Trip
Aided DEF Trip
Aided dist Trip
Aided 1 Send
Not Used
Not Used
VTS
PSB
IM64 2
IM64 3
IM64 4
Not Used
WATCHDOG CONTACT
WATCHDOG CONTACT
RELAY 1
RELAY 32
MiCOM P443 (PART)
OPTO 1
OPTO 32
COMMON CONNECTION
DEFAULT SETTING
Not Used
Not Used
Aid 1 Receive
Aided 1 COS/LGS
Reset LEDs
External Trip A
External Trip B
External Trip C
CB AuxA 52-B
CB AuxB 52-B
CB AuxC 52-B
MCB/VTS
CB Close Manual
Reset Lockout
CB Healthy
BAR
Not Used
Not Used
IM64 1
IM64 2
IM64 3
IM64 4
Not Used
Not Used
Not Used
Not Used
Not Used
Not Used
Not Used
Not Used
Not Used
Not Used
CUSTOMER SETTING
Based on 10P44307 Sheet 3 Issue B
P0332ENa

Figure 22 - P446 D external connections - 32 I/P & 32 O/P


FINISH :- CLEAN
NEXT STAGE :- -
SEE NOTE 2
SEE NOTE 3
ONLY REQUIRED IF ETHERNET COMMS IS FITTED
FOR USA & CANADIAN ORDERS ONLY
YELLOW PRODUCT REGISTRATION LABEL TO BE ATTACHED TO THE FRONT OF THE RELAY UNDER THE BLUE PROTECTIVE FILM ON THE KEYPAD.
SCRAP VIEW SHOWING ACCESS COVER CLOSED
REF 60 TO BE FITTED BEFORE REF 19 & 20
FRONT VIEW (WITH ACCESS COVERS OPEN)
REAR VIEW OF USER INTERFACE
TYPICAL VIEW OF TERMINAL BLOCK LABEL
PCB
FIT JUMPERS 88 (REF 64) TO PL3 ON PCB'S REF 2 IN SLOT POSITIONS SHOWN.
TO BE WRITTEN IN SCREENED CIRCLE. (SEE ALSO NOTE 1)
MAC ADDRESS / SOFTWARE REF. LABEL TO BE FITTED AT FINAL TEST TO ETHERNET COMMS ONLY.
Vx WORKS SOFTWARE LICENCE LABEL TO BE FITTED TO ETHERNET COMMS ONLY.
60 or 61
6 or 7
FRONT VIEW (WITH USER INTERFACE REMOVED)
REAR VIEW
REF 1 & REF 2 TO BE JOINED AS SHOWN
REF 62 SHORT PIN END TO BE INSERTED INTO SK1 ON PCB REF 1
NOTES:
1. ON EACH PCB SERIAL NUMBER TO BE WRITTEN IN SCREENED BOX.
2. IF REF 6 IS NOT REQUIRED FIT REF34 WITH 2 OFF REF61.
3. IF COPROCESSOR REF 7 IS FITTED THEN FIT BLANKING PLATE REF34 WITH 2 OFF REF61.
LABELS
NO LABEL OTHER THAN THOSE LISTED ON THIS SHEET SHOULD APPEAR ON THE RELAY.
IF ADDITIONAL LABELS ARE REQUIRED THE DESIGN OFFICE SHOULD BE NOTIFIED.
THIS NOTE DOES NOT APPLY TO INSPECTION, ASSEMBLY OR QUALITY CONTROL LABELS.
SLOT 1
SLOT 2
SLOT 3
SLOT 4
SLOT 5
SLOT 6
SLOT 9
SLOT 10
SLOT 11
SLOT 12
1
2
3
4
6
19
20
22
24
29
34
40
55
60
62
63
66

	PART	DESCRIPTION OF ASSEMBLY	
		MICOM - P446 DISTANCE	
QTY	REF	DESCRIPTION	MATERIAL
1	1	ASSY POWER SUPPLY	ZN0021 *
*	2	ASSY RELAY OUTPUT	ZN0019 001
2	3	ASSY OPTO INPUT	ZN0017 012
*	4	ASSY HIGH BREAK RELAY OUTPUT	ZN0042 001
*	5	ASSY CURRENT DIFFERENTIAL	GN0107 *
*	6	ASSY IRIG-B/ETHERNET/REAR COMMS	*
*	7	ASSY COPROCESSOR	ZN0020 002
	8		
	9		
	10		
	11		
	12		
	13		
	14		
	15		
	16		
	17		
	18		
1	19	TOP ACCESS COVER	GN6007 003
1	20	BOTTOM ACCESS COVER	GN6007 002
1	21	ASSY CASE	GN0110 *
1	22	ASSY USER INTERFACE	GN0341 *
	23		
1	24	ASSY EXTENDED INPUT MODULE	GN0012 028
	25		
	26		
	27		
	27		
2	29	ASSEMBLY SCREEN PLATE	GN0058 001
	30		
	31		
	32		
	33		
*	34	BLANKING PLATE	GN2037 001
	35		
	36		
	37		
	38		
	39		
1	40	LABEL SHEET - 80TE	GN9011 009
	41		
	42		
	43		
	44		
	45		
	46		
	47		
	48		
	49		
	50		
	51		
	52		
	53		
	54		
*	55	Vx WORKS SOFTWARE	ZB9800 801
*	56	MMS-EASE LITE SOFTWARE	ZB9800 802
	57		
	58		
	59		
*	60	SELF-TAPPING PAN HEAD No4x1/4"	ZB4018 110
*	61	SELF-TAPPING PAN HEAD No6x1/4"	ZB4018 215
1	62	HEADER	ZB9031 985
4	63	SPACER	ZB8011 213
6	64	JUMPER	ZB9031 759
	65		
1	66	ASSY RIBBON CABLE	GN0009 010
	67		
1	68	CUSTOM LED INDICATOR LABEL	GN9025 006
1	69	BAGGED ITEMS - LABELS	GN9091 001
10	70	BAGGED ITEMS - TERMINAL SCREWS	ZA0005 060
2	71	BAGGED ITEMS - FIXING SCREWS	ZA0005 105
	72		
	73		

P0333ENa

Figure 23 - Final assembly - P446 distance relay

Notes:

CYBER SECURITY

CHAPTER 16

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1 OVERVIEW

In the past, substation networks were traditionally isolated and the protocols and data formats used to transfer information between devices were more often than not proprietary.

For these reasons, the substation environment was very secure against cyber attacks. The terms used for this inherent type of security are:

- Security by isolation (if the substation network is not connected to the outside world, it can’t be accessed from the outside world).
- Security by obscurity (if the formats and protocols are proprietary, it is very difficult, to interpret them.

The increasing sophistication of protection schemes coupled with the advancement of technology and the desire for vendor interoperability has resulted in standardization of networks and data interchange within substations. Today, devices within substations use standardized protocols for communication. Furthermore, substations can be interconnected with open networks, such as the internet or corporate-wide networks, which use standardized protocols for communication. This introduces a major security risk making the grid vulnerable to cyber-attacks, which could in turn lead to major electrical outages.

Clearly, there is now a need to secure communication and equipment within substation environments. This chapter describes the security measures that have been put in place for Schneider Electric's range of Intelligent Electronic Devices (IEDs).

2 THE NEED FOR CYBER SECURITY

Cyber-security provides protection against unauthorized disclosure, transfer, modification, or destruction of information and/or information systems, whether accidental or intentional. To achieve this, there are several security requirements:

- Confidentiality (preventing unauthorized access to information)
- Integrity (preventing unauthorized modification)
- Availability / Authentication (preventing the denial of service and assuring authorized access to information)
- Non-Repudiation (preventing the denial of an action that took place)
- Traceability/Detection (monitoring and logging of activity to detect intrusion and analyze incidents)

The threats to cyber security may be unintentional (e.g. natural disasters, human error), or intentional (e.g. cyber attacks by hackers).

Good cyber security can be achieved with a range of measures, such as closing down vulnerability loopholes, implementing adequate security processes and procedures and providing technology to help achieve this.

Examples of vulnerabilities are:

- Indiscretions by personnel (e.g. users keep passwords on their computer)
- Bypassing of controls (e.g. users turn off security measures)
- Bad practice (users do not change default passwords, or everyone uses the same password to access all substation equipment)
- Inadequate technology (e.g. substation is not firewalled)

Examples of availability issues are:

- Equipment overload, resulting in reduced or no performance
- Expiry of a certificate prevents access to equipment.

To help tackle these issues, standards organizations have produced various standards, by which compliance significantly reduces the threats associated with lack of cyber security.

3 STANDARDS

There are several standards, which apply to substation cyber security (see Table 1).

	Country	
NERC CIP (North American Electric Reliability Corporation)	USA	Framework for the protection of the grid critical Cyber Assets
BDEW (German Association of Energy and Water Industries)	Germany	Requirements for Secure Control and Telecommunication Systems
ANSI ISA 99	USA	ICS oriented then Relevant for EPU completing existing standard and identifying new topics such as patch management
IEEE 1686	International	International Standard for substation IED cyber security capabilities
IEC 62351	International	Power system data and Comm. protocol
ISO/IEC 27002	International	Framework for the protection of the grid critical Cyber Assets
NIST SP800-53 (National Institute of Standards and Technology)	USA	Complete framework for SCADA SP800-82and ICS cyber security
CPNI Guidelines (Centre for the Protection of National Infrastructure)	UK	Clear and valuable good practices for Process Control and SCADA security

Table 1 - Standards applicable to cyber security

The standards currently applicable to Schneider Electric IEDs is NERC and IEEE1686.

3.1 NERC Compliance

The North American Electric Reliability Corporation (NERC) created a set of standards for the protection of critical infrastructure. These are known as the CIP standards (Critical Infrastructure Protection). These were introduced to ensure the protection of Critical Cyber Assets, which control or have an influence on the reliability of North America’s bulk electric systems.

These standards have been compulsory in the USA for several years now. Compliance auditing started in June 2007, and utilities face extremely heavy fines for non-compliance.

The group of CIP standards is listed in Table 2.

CIP standard	Description
CIP-002-1 Critical Cyber Assets	Define and document the Critical Assets and the Critical Cyber Assets
CIP-003-1 Security Management Controls	Define and document the Security Management Controls required to protect the Critical Cyber Assets
CIP-004-1 Personnel and Training	Define and Document Personnel handling and training required protecting Critical Cyber Assets
CIP-005-1 Electronic Security	Define and document logical security perimeter where Critical Cyber Assets reside and measures to control access points and monitor electronic access
CIP-006-1 Physical Security	Define and document Physical Security Perimeters within which Critical Cyber Assets reside
CIP-007-1 Systems Security Management	Define and document system test procedures, account and password management, security patch management, system vulnerability, system logging, change control and configuration required for all Critical Cyber Assets

CIP standard	Description
CIP-008-1 Incident Reporting and Response Planning	Define and document procedures necessary when Cyber Security Incidents relating to Critical Cyber Assets are identified
CIP-009-1 Recovery Plans	Define and document Recovery plans for Critical Cyber Assets

Table 2 - NERC CIP standards

The following sections provide further details about each of these standards, describing the associated responsibilities of the utility company and where the IED manufacturer can help the utilities with the necessary compliance to these standards.

3.1.1 CIP 002

CIP 002 concerns itself with the identification of:

- Critical assets, such as overhead lines and transformers
- Critical cyber assets, such as IEDs that use routable protocols to communicate outside or inside the Electronic Security Perimeter; or are accessible by dial-up.

Power utility responsibilities:	Schneider Electric's contribution:
Create the list of the assets	We can help the power utilities to create this asset register automatically. We can provide audits to list the Cyber assets

3.1.2 CIP 003

CIP 003 requires the implementation of a cyber security policy, with associated documentation, which demonstrates the management’s commitment and ability to secure its Critical Cyber Assets.

The standard also requires change control practices whereby all entity or vendor-related changes to hardware and software components are documented and maintained

Power utility responsibilities:	Schneider Electric's contribution:
To create a Cyber Security Policy	We can help the power utilities to have access control to its critical assets by providing centralized Access control. We can help the customer with its change control by providing a section in the documentation where it describes changes affecting the hardware and software.

3.1.3 CIP 004

CIP 004 requires that personnel having authorized cyber access or authorized physical access to Critical Cyber Assets, (including contractors and service vendors), have an appropriate level of training.

Power utility responsibilities:	Schneider Electric's contribution:
To provide appropriate training of its personnel	We can provide cyber security training

3.1.4 CIP 005

CIP 005 requires the establishment of an Electronic Security Perimeter (ESP), which provides:

- The disabling of ports and services that are not required

- Permanent monitoring and access to logs (24x7x365)
- Vulnerability Assessments (yearly at a minimum)
- Documentation of Network Changes

Power utility responsibilities:	Schneider Electric's contribution:
To monitor access to the ESP To perform the vulnerability assessments To document network changes	To disable all ports not used in the IED To monitor and record all access to the IEDthe access at all access points of the ESP

3.1.5 CIP 006

CIP 006 states that Physical Security controls, providing perimeter monitoring and logging along with robust access controls, must be implemented and documented. All cyber assets used for Physical Security are considered critical and should be treated as such:

Power utility responsibilities:	Schneider Electric's contribution:
Provide physical security controls and perimeter monitoring. Ensure that people who have access to critical cyber assets don’t have criminal records Schneider Electric's contribution.	Schneider Electric cannot provide additional help with this aspect.

3.1.6 CIP 007

CIP 007 covers the following points:

- Test procedures
- Ports and services
- Security patch management
- Antivirus
- Account management
- Monitoring
- An annual vulnerability assessment should be performed

Power utility responsibilities:	Schneider Electric's contribution:
To provide an incident response team and have appropriate processes in place	Test procedures; We can provide advice and help on testing. Ports and services; Our devices can disable unused ports and services Security patch management; We can provide assistance Antivirus; We can provide advise and assistance Account management; We can provide advice and assistance Monitoring; Our equipment monitors and logs access

3.1.7 CIP 008

CIP 008 requires that an incident response plan be developed, including the definition of an incident response team, their responsibilities and associated procedures.

Power utility responsibilities:	Schneider Electric's contribution:
To provide an incident response team and have appropriate processes in place.	Schneider Electric cannot provide additional help with this aspect.

3.1.8 CIP 009

CIP 009 states that a disaster recovery plan should be created and tested with annual drills.

Power utility responsibilities:	Schneider Electric's contribution:
To implement a recovery plan	To provide guidelines on recovery plans and backup/restore documentation

3.2 IEEE 1686-2007

IEEE 1686-2007 is an IEEE Standard for substation IEDs cyber security capabilities. It proposes practical and achievable mechanisms to achieve secure operations.

The following features described in this standard apply to Schneider Electric Px40 relays:

- Passwords are 8 characters long and can contain upper-case, lower-case, numeric and special characters.
- Passwords are never displayed or transmitted to a user.
- IED functions and features are assigned to different password levels. The assignment is fixed.
- Record of an audit trail listing events in the order in which they occur, held in a circular buffer.
- Records contain all defined fields from the standard and record all defined function event types where the function is supported.
- No password defeat mechanism exists. Instead a secure recovery password scheme is implemented.
- Unused ports (physical and logical) may be disabled.

4 PX40 CYBER SECURITY IMPLEMENTATION

The Schneider Electric IEDs have always been and will continue to be equipped with state-of-the-art security measures. Due to the ever-evolving communication technology and new threats to security, this requirement is not static. Hardware and software security measures are continuously being developed and implemented to mitigate the associated threats and risks.

This section describes the current implementation of cyber security, valid for the release of platform software to which this manual pertains. This current cyber security implementation is known as Cyber Security Phase 1.

At the IED level, these cyber security measures have been implemented:

- Four-level Access
- Password strengthening
- Disabling of unused application and physical ports
- Inactivity timer
- Storage of security events (logs) in the IED
- NERC-compliant default display

External to the IEDs, the following cyber security measures have been implemented:

- Antivirus
- Security patch management

4.1 Four-level Access

The menu structure contains four levels of access three of which are password protected. These are summarized in Table 3.

Level	Meaning	Read Operation	Write Operation
0	Read Some Write Minimal	SYSTEM DATA column: Description Plant Reference Model Number Serial Number S/W Ref. Access Level Security Feature SECURITY CONFIG column: User Banner Attempts Remain Blk Time Remain Fallback PW level Security Code (UI only)	Password Entry LCD Contrast (UI only)
1	Read All Write Few	All data and settings are readable. Poll Measurements	All items writeable at level 0. Level 1 Password setting Select Event, Main and Fault (upload) Extract Events (e.g. via MiCOM S1 Studio)

Level	Meaning	Read Operation	Write Operation
2	Read All Write Some	All data and settings are readable. Poll Measurements	All items writeable at level 1. Setting Cells that change visibility (Visible/Invisible). Setting Values (Primary/Secondary) selector Commands: Reset Indication Reset Demand Reset Statistics Reset CB Data / counters Level 2 Password setting
3	Read All Write All	All data and settings are readable. Poll Measurements	All items writeable at level 2. Change all Setting cells Operations: Extract and download Setting file. Extract and download PSL Extract and download MCL61850 (IED Config - IEC61850) Extraction of Disturbance Recorder Courier/Modbus Accept Event (auto event extraction, e.g. via A2R) Commands: Change Active Group setting Close / Open CB Change Comms device address. Set Date & Time Switch MCL banks / Switch Conf. Bank in UI (IED Config - IEC61850) Enable / Disable Device ports (in SECURITY CONFIG column) Level 3 password setting

Table 3 - Password levels

4.1.1 Default Passwords

Default passwords are blank for Level 1 and AAAA for Levels 2 and 3.

4.1.2 Password Rules

- Passwords may be any length between 0 and 8 characters long
- Passwords may or may not be NERC compliant
- Passwords may contain any ASCII character in the range ASCII code 33 (21 Hex) to ASCII code 122 (7A Hex) inclusive
- Only one password is required for all the IED interfaces

4.1.3 Access Level DDBs

In additional to having the 'Access level' cell in the 'System data' column (address 00D0), the current level of access for each interface is also available for use in the Programming Scheme Logic (PSL) by mapping to these Digital Data Bus (DDB) signals:

- HMI Access Lvl 1
- HMI Access Lvl 2
- FPort AccessLvl1
- FPort AccessLvl2
- RPrt1 AccessLvl1
- RPrt1 AccessLvl2
- RPrt2 AccessLvl1
- RPrt2 AccessLvl2

Where:

HMI is the Human Machine Interface.

Each pair of DDB signals indicates the access level as follows:

- Lvl 1 off, Lvl 2 off = 0
- Lvl 1 on, Lvl 2 off = 1
- Lvl 1 off, Lvl 2 on = 2
- Lvl 1 on, Lvl 2 on = 3

4.2

Password Strengthening

NERC compliant passwords result in a minimum level of complexity, and include these requirements:

- At least one upper-case alpha character
- At least one lower-case alpha character
- At least one numeric character
- At least one special character (%,$...)
- At least six characters long

4.3

Password validation

The IED checks for NERC compliance. If the password is entered through the front panel then this is reflected on the panel Liquid Crystal Display (LCD) display.

If the entered password is NERC compliant, the following text is displayed

```
NERC COMPLIANT
P/WORD WAS SAVED
```

The IED does not enforce NERC compliance. It is the responsibility of the user to ensure that compliance is adhered to as and when necessary. In the case that the password entered is not NERC-compliant, the user is required to actively confirm this, in which case the non-compliance is logged.

If the entered password is not NERC compliant, the following text is displayed:

```
NERC COMPLIANCE
NOT MET CONFIRM?
```

On confirmation, the non-compliant password is stored and the following acknowledgement message is displayed for 2 seconds.

```
NON-NERC P/WORD
SAVED OK
```

If the action is cancelled, the password is rejected and the following message displayed for 2 seconds.

```
NON-NERC P/WORD
NOT SAVE
```

If the password is entered through a communications port using Courier or Modbus protocols the IED will store the password, irrespective of whether it is or isn't NERC-compliant, and then uses appropriate response codes to inform the client that the password was NERC-compliant or not. The client then can choose if he/she wishes to enter a new password that is NERC-compliant or leave the entered one in place.

4.3.1 Blank Passwords

A blank password is effectively a zero-length password. Through the front panel it is entered by confirming the password entry without actually entering any password characters. Through a communications port the Courier and Modbus protocols each have a means of writing a blank password to the IED. A blank password disables the need for a password at the level that this password applied.

Blank passwords have a slightly different validation procedure. If a blank password is entered through the front panel, the following text is displayed, after which the procedure is the same as already described:

```
BLANK PASSWORD
ENTERED CONFIRM
```

Blank Passwords cannot be configured if lower level password is not blank.

Blank Passwords affect fall back level after inactivity timeout or logout.

The 'fallback level' is the password level adopted by the IED after an inactivity timeout, or after the user logs out. This will be either the level of the highest level password that is blank, or level 0 if no passwords are blank.

4.4 Password Management

The user is locked out temporarily, after a defined number of failed password entry attempts. The number of password entry attempts, and the blocking periods are configurable. These settings are shown in Table 4.

The first invalid password entry sets the attempts count (actual text here) to 1 and initiates an 'attempts timer'. Further invalid passwords during the timed period increments the attempts count. When the maximum number of attempts has been reached, access is blocked. If the attempts timer expires, or the correct password is entered *before* the 'attempt count' reaches the maximum number, then the 'attempts count' is reset to 0.

Once the password entry is blocked, a 'blocking timer' is initiated. Attempts to access the interface whilst the 'blocking timer' is running results in an error message, irrespective of whether the correct password is entered or not. Only after the 'blocking timer' has expired will access to the interface be unblocked, whereupon the attempts counter is reset to zero.

Attempts to write to the password entry whilst it is blocked results in the following message, which is displayed for 2 seconds.

```
NOT ACCEPTED
ENTRY IS BLOCKED
```

Appropriate responses achieve the same result if the password is written through a communications port.

The attempts count, attempts timer and blocking timer can be configured, as shown in Table 4.

Setting	Cell col row	Units	Default Setting	Available Setting
Attempts Limit	25 02		3	0 to 3 step 1
Attempts Timer	25 03	Minutes	2	1 to 3 step 1
Blocking Timer	25 04	Minutes	5	1 to 30 step 1

Table 4 - Password blocking configuration

4.5 Password Recovery

Password recovery is the means by which the passwords can be recovered on a device if the customer should mislay the configured passwords. To obtain the recovery password the customer must contact the Schneider Electric Contact Center and supply two pieces of information from the IED – namely the *Serial Number* and its *Security Code*. The Contact Centre will use these items to generate a Recovery Password which is then provided to the customer.

The security code is a 16-character string of upper case characters. It is a read-only parameter. The IED generates its own security code randomly. A new code is generated under the following conditions:

- On power up
- Whenever settings are set back to default
- On expiry of validity timer (see below)
- When the recovery password is entered

As soon as the security code is displayed on the LCD display, a validity timer is started. This validity timer is set to 72 hours and is not configurable. This provides enough time for the contact centre to manually generate and send a recovery password. The Service Level Agreement (SLA) for recovery password generation is one working day, so 72 hours is sufficient time, even allowing for closure of the contact centre over weekends and bank holidays.

To prevent accidental reading of the IED security code the cell will initially display a warning message:

```
PRESS ENTER TO
READ SEC. CODE
```

The security code will be displayed on confirmation, whereupon the validity timer will be started. Note that the security code can only be read from the front panel.

4.5.1 Entry of the Recovery Password

The recovery password is intended for recovery only. It is not a replacement password that can be used continually. It can only be used once – for password recovery.

Entry of the recovery password causes the IED to reset all passwords back to default. This is all it is designed to do. After the passwords have been set back to default, it is up to the user to enter new passwords appropriate for the function for which they are intended, ensuring NERC compliance, if required.

On this action, the following message is displayed:

```
PASSWORDS HAVE
BEEN SET TO DEFAULT
```

The recovery password can be applied through any interface, local or remote. It will achieve the same result irrespective of which interface it is applied through.

4.5.2 Password Encryption

The IED supports encryption for passwords entered remotely. The encryption key can be read from the IED through a specific cell available only through communication interfaces, not the front panel. Each time the key is read the IED generates a new key that is valid only for the next password encryption write. Once used, the key is invalidated and a new key must be read for the next encrypted password write. The encryption mechanism is otherwise transparent to the user.

4.6 Port Disablement

4.6.1 Disabling Physical Ports

It is possible to disable unused physical ports. A level 3 password is needed to perform this action.

To prevent accidental disabling of a port, a warning message is displayed according to whichever port is required to be disabled. For example if rear port 1 is to be disabled, the following message appears:

```
REAR PORT 1 TO BE
DISABLED.CONFIRM
```

There are between two and four ports eligible for disablement:

- Front port
- Rear port 1
- Rear port 2 (not implemented on all models)
- Ethernet port (not implemented on all models)

Note *It is not possible to disable a port from which the disabling port command originates.*

4.6.2 Disabling Logical Ports

It is possible to disable unused logical ports. A level 3 password is needed to perform this action.

Note *The port disabling setting cells are not provided in the settings file*

Caution **Disabling the Ethernet port will disable all Ethernet based communications.**

If it is not desirable to disable the Ethernet port, it is possible to disable selected protocols on the Ethernet card and leave others functioning.

Three protocols can be disabled:

- IEC61850

- DNP3 Over Ethernet
- Courier Tunnelling

Note	*If any of these protocols are enabled or disabled, the Ethernet card will reboot.*

4.7 Logging out

If you have been configuring the IED, you should 'log out'. You do this by going up to the top of the menu tree. When you are at the Column Heading level and you press the Up button, you may be prompted to log out with the following display:

```
DO YOU WANT TO
LOG OUT?
```

You will only be asked this question if your password level is higher than the fallback level.

If you confirm, the following message is displayed for 2 seconds:

```
LOGGED OUT
Access Level <x>
```

Where x is the current fallback level.

If you decide not to log out (i.e. you cancel), the following message is displayed for 2 seconds.

```
LOGOUT CANCELLED
Access Level <x>
```

Where x is the current access level.

4.8 Events

The implementation of NERC-compliant cyber security necessitates the generation of a range of Event records, which log security issues such as the entry of a non-NERC-compliant password, or the selection of a non-NERC-compliant default display. Table 6 lists all Security events.

Event Value	Display
PASSWORD LEVEL UNLOCKED	USER LOGGED IN ON <int> LEVEL <n>
PASSWORD LEVEL RESET	USER LOGGED OUT ON <int> LEVEL <n>
PASSWORD SET BLANK	P/WORD SET BLANK BY <int> LEVEL <p>
PASSWORD SET NON-COMPLIANT	P/WORD NOT-NERC BY <int> LEVEL <p>
PASSWORD MODIFIED	PASSWORD CHANGED BY <int> LEVEL <p>
PASSWORD ENTRY BLOCKED	PASSWORD BLOCKED ON <int>
PASSWORD ENTRY UNBLOCKED	P/WORD UNBLOCKED ON <int>
INVALID PASSWORD ENTERED	INV P/W ENTERED ON <int>

Event Value	Display
PASSWORD EXPIRED	P/WORD EXPIRED ON <int>
PASSWORD ENTERED WHILE BLOCKED	P/W ENT WHEN BLK ON <int>
RECOVERY PASSWORD ENTERED	RCVY P/W ENTERED ON <int>
IED SECURITY CODE READ	IED SEC CODE RD ON <int>
IED SECURITY CODE TIMER EXPIRED	IED SEC CODE EXP -
PORT DISABLED	PORT DISABLED BY <int> PORT <prt>
PORT ENABLED	PORT ENABLED BY <int> PORT <prt>
DEF. DISPLAY NOT NERC COMPLIANT	DEF DSP NOT-NERC
PSL SETTINGS DOWNLOADED	PSL STNG D/LOAD BY <int> GROUP <grp>
DNP SETTINGS DOWNLOADED	DNP STNG D/LOAD BY <int>
TRACE DATA DOWNLOADED	TRACE DAT D/LOAD BY <int>
IEC61850 CONFIG DOWNLOADED	IED CONFG D/LOAD BY <int>
USER CURVES DOWNLOADED	USER CRV D/LOAD BY <int> GROUP <crv>
PSL CONFIG DOWNLOADED	PSL CONFG D/LOAD BY <int> GROUP <grp>
SETTINGS DOWNLOADED	SETTINGS D/LOAD BY <int> GROUP <grp>
PSL SETTINGS UPLOADED	PSL STNG UPLOAD BY <int> GROUP <grp>
DNP SETTINGS UPLOADED	DNP STNG UPLOAD BY <int>
TRACE DATA UPLOADED	TRACE DAT UPLOAD BY <int>
IEC61850 CONFIG UPLOADED	IED CONFG UPLOAD BY <int>
USER CURVES UPLOADED	USER CRV UPLOAD BY <int> GROUP <crv>
PSL CONFIG UPLOADED	PSL CONFG UPLOAD BY <int> GROUP <grp>
SETTINGS UPLOADED	SETTINGS UPLOAD BY <int> GROUP <grp>
EVENTS HAVE BEEN EXTRACTED	EVENTS EXTRACTED BY <int> <nov> EVNTS
ACTIVE GROUP CHANGED	ACTIVE GRP CHNGE BY <int> GROUP <grp>
CS SETTINGS CHANGED	C & S CHANGED BY <int>
DR SETTINGS CHANGED	DR CHANGED BY <int>

Event Value	Display
SETTING GROUP CHANGED	SETTINGS CHANGED BY <int> GROUP <grp>
POWER ON	POWER ON -
SOFTWARE_DOWNLOADED	S/W DOWNLOADED -

Table 5 - Security event values

Where:

int is the interface definition (UI, FP, RP1, RP2, TNL, TCP)
prt is the port ID (FP, RP1, RP2, TNL, DNP3, IEC, ETHR)
grp is the group number (1, 2, 3, 4)
crv is the Curve group number (1, 2, 3, 4)
n is the new access level (0, 1, 2, 3)
p is the password level (1, 2, 3)
nov is the number of events (1 – nnn)

Each event is identified with a unique number that is incremented for each new event so that it is possible to detect missing events as there will be a ‘gap’ in the sequence of unique identifiers. The unique identifier forms part of the event record that is read or uploaded from the IED.

Note *It is no longer possible to clear Event, Fault, Maintenance, and Disturbance Records*

4.9 Cyber Security Settings

Cyber Security is important enough to warrant its own IED column called SECURITY CONFIGURATION, located at column number 25. In addition to this new group, settings are affected in the SYSTEM DATA, COMMS SYS DATA and VIEW RECORDS columns.

A summary of the relevant columns is shown in Table 6. A complete listing of the settings criteria is described in the Settings and Records chapter.

Parameter	Cell col row	Default Setting	Available Setting	Interface Applicability	In Setting file?
Password	00 02		ASCII 33 to 122	All	Yes, ~~~~~~~~
Access Level	00 D0		0 = Read Some, 1 = Read All, 2 = Read All + Write Some, 3 = Read All + Write All	All	Yes, Not Settable
Password Level 1	00 D2		ASCII 33 to 122	All	Yes
Password Level 2	00 D3		ASCII 33 to 122	All	Yes
Password Level 3	00 D4		ASCII 33 to 122	All	Yes
Security Feature	00 DF		1	All	Yes, Not Settable
SECURITY CONFIG	25 00			All	Yes
Use Banner	25 01	ACCESS ONLY FOR AUTHORISED USERS	ASCII 32 to 163	All	Yes
Attempts Limit	25 02	3	0 to 3 step 1	All	Yes
Attempts Timer	25 03	2	1 to 3 step 1	All	Yes
Blocking Timer	25 04	5	1 to 30 step 1	All	Yes

Parameter	Cell col row	Default Setting	Available Setting	Interface Applicability	In Setting file?
Front Port	25 05	Enabled	0 = Disabled or 1 = Enabled	All	No
Rear Port 1	25 06	Enabled	0 = Disabled or 1 = Enabled	All	No
Rear Port 2	25 07	Enabled	0 = Disabled or 1 = Enabled	All	No
Ethernet Port*	25 08	Enabled	0 = Disabled or 1 = Enabled	All	No
Courier Tunnel*†	25 09	Enabled	0 = Disabled or 1 = Enabled	All	No
IEC61850*†	25 0A	Enabled	0 = Disabled or 1 = Enabled	All	No
DNP3 OE*†	25 0B	Enabled	0 = Disabled or 1 = Enabled	All	No
Attempts Remain	25 11			All	Yes, Not Settable
Blk Time Remain	25 12			All	Yes, Not Settable
Fallbck PW Level	25 20	0	0 = Password Level 0, 1 = Password Level 1, 2 = Password Level 2, 3 = Password Level 3	All	Yes, Not Settable
Security Code	25 FF			UI Only	No
Evt Unique Id (Normal Extraction)	01 FE			All	No
Evt Iface Source ± (Bits 0 – 7 of Event State)	01 FA			All	No
Evt Access Level ± (Bits 15 – 8 of Event State)	01 FB			All	No
Evt Extra Info 1 ± (Bits 23 – 16 of Event State)	01 FC			All	No
Evt Extra Info 2 ±Ω (Bits 31 – 24 of Event State)	01 FD			All	No

Table 6 - Security cells summary

Where:
* - These cells will not be present in a non-Ethernet product
†- These cells will be invisible if the Ethernet port is disabled.
± - These cells invisible if event is not a Security event
Ω – This cell is invisible in current phase as it does not contain any data. Reserved for future use.

VERSION HISTORY

CHAPTER 17

Date:	02/2013
Hardware suffix:	M
Software version:	D0
Connection diagrams:	10P44303 (SH 01 and 03) 10P44304 (SH 01 and 03) 10P44305 (SH 01 and 03) 10P44306 (SH 01 and 03) 10P44600 10P44601 (SH 1 to 2) 10P44602 (SH 1 to 2) 10P44603 (SH 1 to 2)

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Notes:

1 VERSION HISTORY

Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	Minor					
20	B	G	May 2004	Original Issue P443 only	V2.10	-
30	A	J	Dec 2004	Release of P443. Manufacturer details changed to AREVA. Dual opto input operate/reset characteristics. Fiber optic support for Courier/DNP3.0 protocols. Fault record data available over IEC60870-5-103 protocol. Improved time synchronization accuracy. Improved measurement refresh. Improved scheme logic stability. Improved operation for powerswing conditions. Improved operation for evolving faults. Additional weak infeed detector added to block operation of ground elements with zero sequence infeed only	Patch available for V2.10 onwards	-
31	A	J	Aug 2005	Release of P443 based on 30A. Improved stability under powerswing conditions. Accurate phase selection and directional stability for faults occurring during powerswing. Permissive Overreach Weak Infeed scheme improved stability. Improved operation of the phase selector and distance elements for evolving faults	Patch available for V2.10 onwards	-
32	A	J	Oct 2005	Release of P443 based on 31A. Support for InterMiCOM^{64} fiber optic communications	Patch available for V2.10 onwards	-
32	B	J	Nov 2005	Release of P443 & P445 based on 32A. Check synchronization for manual closure corrected. Non-volatile storage of control Inputs Implemented. Launch of P445 model	Patch available for V2.10 onwards	-
32	C	J	Nov 2005	Release of P443 & P445 based on 32B. Correction to InterMiCOM^{64} fiber optic communications	Patch available for V2.10 onwards	-
32	D	J	Jan 2006	Release of P443 & P445 based on 32C. Correction to InterMiCOM^{64} fiber optic communications loopback alarm	Patch available for V2.10 onwards	-
33	A	J	May 2006	Release of P443 & P445 based on 32D. Out of step protection implemented (P443 only)	Patch available for V2.10 onwards V2.13 or Later	P44y/EN M/B21
33	B	J	15 May 2007	Release of P443 & P445 based on 33A. Fixed CTS blocking of earth fault and broken conductor. Prevented SOTF operating when it is disabled. Out of step tripping Delta t step size	Patch available for V2.10 onwards V2.13 or Later	P44y/EN M/B21

Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	Minor					
33	B	J	15 May 2007	When check synch is blocked by under or over voltage, both bus and line voltage inputs need to be at the reset level rather than having independent operation, also CS Overvoltage problem. Auto-reclose dead time/close cycle continues even if AR switched out of service. Prevented P445 CS103 rebooting when extracting fault records. Prevented P445 operation of delta scheme when AIDED 2 POR scheme selected. Corrected Disturbance recorder scaling to prevent high current levels into 5A CT causing the Disturbance Recorder to saturate. Restring defaults appears not to change the 1/5A CT selection. Auto-reclose dead time/close cycle continues even if AR switched out of service. Distance setting are not updated in simple setting mode in setting groups other than the active one	Patch available for V2.10 onwards V2.13 or Later	P44y/EN M/B21
33	C	J	22 Jan 2008	Release of P443 & P445 based on 33B. Fixed CT/VT ratios scaling of Zone 5 & Zone 6 settings. Fixed a problem with week infeed inhibit. Fixed a SOTF problem when there is a short duration pre-fault. Corrected calculation of Z3 Gnd Rev Reach. Corrections to over voltage stage 2 inhibit	Patch available for V2.10 onwards V2.13 or Later	P44y/EN M/B21
33	C	J	22 Jan 2008	Corrected IM64 Test Mode Alarm which could remain even when IM64 is disabled	Patch available for V2.10 onwards V2.13 or Later	P44y/EN M/B21
33	D	J	20 Aug 2008	Release of P443 & P445 based on 33C. Fix to Blocking scheme. Fix for DEF reverse operation. Prevented CB Operating Time displaying 4.295Ms. Bug fixes	Patch available for V2.10 onwards V2.13 or Later	P44y/EN M/B21
35	B	J	25 Jun 2008	Release of P445 based on P443 54B. First release.	Patch available for V2.14 First release of Studio	P445/EN M/A11
35	C	J		Not released. Based on P445 35B. Correction to auto-reclose operation for switch on to fault condition.	Patch available for V2.14 First release of Studio	P445/EN M/A11
35	D	J	20 Jan 2009	Release of P445 based on P445 35C. Corrections to default PSL. Correction to the distance cross polarizing when the memory expires. Corrected Thermal State measurement via DNP3. Timestamp in fault record adjusted for the local time setting	Patch available for V2.14 First release of Studio	P445/EN M/A11
35	D	J	20 Jan 2009	Corrected Breaker Fail - WI Aided1 trips so they can be disabled via setting "WI Prot Reset"	Patch available for V2.14 First release of Studio	P445/EN M/A11

Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	Minor					
35	E	J	30 Mar 2009	Release of P445 based on P445 35D. Prevents the loss of IEC61850 messages and fixed the handling of the ACD flag during GI. Improved the Ethernet card boot code	Patch available for V2.14 First release of Studio	P445/EN M/A11
51	C	K	27 Jul 2006	Release of P443 based on 32B. Standard and Inverted CT polarity setting for each set of CTs in the relay. User interface with tri colored LED and Function keys. IEC61850-8-1. High Break options. Unmodulated IRIG-B options. Reduction of distance minimum reach settings to 0.05 ohm. Permissive Trip reinforcement. Poledead modifications for Hydro Quebec. CS103/Auto-reclose modifications. Out of Step Tripping	Patch available for V2.12 V2.13 or Later	P443/EN M/A22
51	D	K	16 Aug 2006	Release of P443 based on 51C. Prevents a possible reboot 15 minutes after browsing the front courier port but not not making a setting change i.e. browsing using PAS&T. Minor correction to add Aided Delta trip to POR scheme send carrier on trip logic in P443. Extended GOOSE enrolment capability. Correction to ICD files, enumeration (value) and fixed data mapping	Patch available for V2.12 V2.13 or Later	P443/EN M/A22
51	E	K	14 Nov 2006	Release of P443 based on 51D. Prevent a reboot in 61850 builds when NIC link is inactive and avalanche of DDB activity. Correctly report a fatal error generated by the sampling call-back. Correct the operation of the GOOSE messaging and a problem with the download of an IED configuration file. Correct the operation of the check sync. Correct the operation of the overcurrent reset curves. Removed check on the14th position of model number. Fixed Telegrams for public inf 64-67 . SOTF can operate even when it is disabled	Patch available for V2.12 V2.13 or Later	P443/EN M/A22
51	F	K	15 May 2007	Release of P443 non 61850 builds based on 51E. Prevent a fatal error from an incorrect DNP address in not using DNP evolutions platform.	Patch available for V2.12 V2.13 or Later	P443/EN M/A22

Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	Minor					
51	F	K	15 May 2007	Default setting for 450B 'I< Current Set' reduced to 50mA. French Translations for DDBs 1368-1371corrected. Dependencies for cells 3242 & 3245 corrected. Fun & INF values related to CS103 Command Blocking corrected. Angle for negative sequence phase overcurrent setting corrected. Corrected operation when using MiCOM S1 is used to activate Settings group by right clicking on the group. Corrected the latching of Function Key DDB signals on relay power up. Corrected Disturbance recorder scaling to prevent high current levels into 5A CT causing the Disturbance Recorder to saturate. Restring defaults appears not to change the 1/5A CT selection. Corrected the performance of the IM64 Direct mode. Auto-reclose dead time/close cycle continues even if AR switched out of service. Distance setting are not updated in simple setting mode in setting groups other than the active one. Ch2 Statistics may not be displayed	Patch available for V2.12 V2.13 or Later	P443/EN M/A22
51	G	K		P443 non 61850 builds based on 51F was approved for release but withdrawn before release. Corrections to enable/disable of auto-reclose	Patch available for V2.12 V2.13 or Later	P443/EN M/A22
51	H	K	4 Jul 2007	P443 non 61850 builds based on 51G released. Corrections to enable/disable of Auto-reclose	Patch available for V2.12 V2.13 or Later	P443/EN M/A22
52	A	K		Release of P443 based on 51E. Chinese interface. Replacing the existing DNP3 with the DNP3 evolutions. Addition of a current but no volts trip option to Switch on to Fault and Trip on re-close feature (SOTF/TOR). Replacement of existing negative sequence overcurrent with multi stage (2 IDMT + 2 DT) negative sequence overcurrent. Addition of IDG curve, commonly used in Sweden, to Earth Fault & Sensitive Earth Fault (involves moving settings). Reduction of all TMS step sizes to 0.005. Changes to CTS so both techniques can be selected together. Regrouping of CTS settings. Addition of four stages of under frequency protection and two stages of Overfrequency protection. Addition of df/dt protection. Changes to Under and Overvoltage to enable each stage to be independently set. Extensions to the checksync VT position setting. Replacing fixed Trip on Close (TOC) delay with a setting	Patch available for V2.14	P443/EN M/A22 + Addendum

Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	**Minor**					
52	A	K		Improvements to slow power swing detection. Includes local time zone settings for Date & Time. Addition of flexible settings for distance quadrilateral top line. Reduced minimum setting for IN> I2pol set. Addition of propagation delay times to Fault Record. Default setting for 450B 'I< Current Set' reduced to 50mA. Enhancement to self checking of output relays. Change tunneled courier address to follow the 1st Rear Port's KBUS or CS103 address.	Patch available for V2.14	P443/EN M/A22 + Addendum
52	B	K	4 Jul 2007	Release of P443 based on 52A. Extra fiber options for P443. Improvements to VTS. Improvements to slow power swing detection. Corrections to enable/disable of auto-reclose. Resolved a problem relating to CT ratio's not being restored when restoring default settings. Resolved a problem with the Disturbance Recorder which saturates for High current levels into 5A CT	Patch available for V2.14	P443/EN M/A22 + Addendum
52	C	K	31 Jul 2007	Release of P443 based on 52B. Tilt angle of ground quadrilateral characteristic corrected. Minor correction to fault record. Corrections to over voltage stage 2 inhibit	Patch available for V2.14	P443/EN M/A22 + Addendum
52	D	K	17 Dec 2007	Release of P443 based on 52C. Fixed a number of 61850/Goose problems. Corrected some DDB German text. Fixed a problem with week infeed inhibit. Fixed a SOTF problem when there is a short duration pre-fault. Fixed a primary scaling issue relating to Zone 5 & 6	Patch available for V2.14	P443/EN M/A22 + Addendum
52	E	K	15 May 2008	Release of P443 based on 52D. Fixed a number of 61850 problems. Improved co-processor error reporting. Fix to Blocking scheme	Patch available for V2.14	P443/EN M/A22 + Addendum
52	F	K	24 Oct 2008	Not released. Based on 52E. Correction to auto-reclose operation for switch on to fault condition. Prevented CB Operating Time displaying 4.295Ms. Bug fixes	Patch available for V2.14	P443/EN M/A22 + Addendum
52	G	K	28 Oct 2008	Release of P443 based on 52F. Correction to the distance cross polarizing when the memory expires	Patch available for V2.14	P443/EN M/A22 + Addendum

Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	**Minor**					
52	H	K	21 Sept 2009	Release of P443 based on 52G. Corrected some menu translations. Corrected Breaker Fail - WI Aided1 trips so they can be disabled via setting "WI Prot Reset". Timestamp in fault record adjusted for the local time setting. Corrected Thermal State measurement via DNP3. Correction to the way latched LED/Relays are cleared . Correction to Negative sequence overcurrent settings when 5A input used. Prevent Z5 from setting slow swing when PSB is disabled. Fixed problem which prevented residual overvoltage from initiating CB Fail. Various improvements to DNP, CS103 & IEC61850 protocols. Bug fixes	Patch available for V2.14	P443/EN M/A22 + Addendum
54	A	K	8 May 2008	Release of P443 based on 52D. Positional information added to PSL. DNP 3.0 Over Ethernet protocol added	Patch available for V2.14 First release of Studio	P443/EN M/B42
54	A	K	8 May 2008	Extended I/O - status inputs increased from 24 to 32. Compensated overvoltage protection added. IEC-103 generic services measurements added. Set/Reset latch logic gates added to PSL. Improved sensitivity range for DEF. Fault record increased max number of fault records to 15. DNP enhancements for SSE. Bug fixes	Patch available for V2.14 First release of Studio	P443/EN M/B42
54	B	K	25 Jun 2008	Release of P443 based on 54A. Fixed a number of 61850 problems. Improved co-processor error reporting. Fix to Blocking scheme. Fix for DEF reverse operation. Corrected some French and German text. Prevented CB operating time displaying 4.295Ms. Fixed a problem which prevented extraction of DNP3 setting files from dnp3 over Ethernet variants. Bug fixes	Patch available for V2.14 First release of Studio	P443/EN M/B42
54	C	K	1 Oct 2008	Release of P443 based on 54B. Correction to auto-reclose operation for switch on to fault condition	Patch available for V2.14 First release of Studio	P443/EN M/B42
54	D	K	20 Jan 2009	Release of P443 based on 54C. Correction to the distance cross polarizing when the memory expires. Corrected Thermal State measurement via DNP3. Timestamp in fault record adjusted for the local time setting. Corrected Breaker Fail - WI Aided1 trips so they can be disabled via setting "WI Prot Reset"	Patch available for V2.14 First release of Studio	P443/EN M/B42
54	E	K	20 Mar 2009	Release of P443 based on 54D. Prevents the loss of IEC61850 messages and fixed the handling of the ACD flag during GI. Improved the Ethernet card boot code	Patch available for V2.14 First release of Studio	P443/EN M/B42

Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	Minor					
54	F	K	21 Sept 2009	Release of P443 based on 54E. Corrected some menu translations. Correction to the way latched LED/Relays are cleared . Correction to Negative sequence overcurrent settings when 5A input used. Prevent Z5 from setting slow swing when PSB is disabled. Fixed problem which prevented residual overvoltage from initiating CB Fail. Various improvements to DNP, CS103 & IEC61850 protocols. Bug fixes	Patch available for V2.14 First release of Studio	P443/EN M/B42
55	B	K	30 Mar 2009	Release of P443 & P446 based on 54E. New P446 which includes auto-reclose, check sync and CB monitoring	Patch for V2.14 Studio ftp server	P44y/EN M/C32
55	C	K	May 2009	Release of P443 & P446 based on 55B. Improvements to the Ethernet card startup and configuration. Correction to Negative sequence overcurrent settings when 5A input used. Correction to the way latched LED/Relays are cleared . Corrections to menu text. Bug Fixes	Patch for V2.14 Studio ftp server	P44y/EN M/C32
55	D	K	October 2009	Release of P443 & P446 based on 55C. Correction to slow power swing configuration. Prevent Z5 from setting slow swing when PSB is disabled. Bug Fixes	Patch for V2.14 Studio ftp server	P44y/EN M/C32
57	A	K		Limited Release of P443 & P446 based on 55D. IEC-61850 phase 2 and 2.1 implemented. Restricted Earth Fault Protection (REF). Separate measurements for each set of CT's. Interrupt Driven InterMiCOM in all models. Read Only Mode	Patch for V2.14 Studio ftp server	P44y/EN M/C32 + addendum P44y/EN AD/D32
57	B	K	January 2010	Release of P443 & P446 based on 57A. Fault locator measurements in ohms corrected when 5A CT used or displayed in primary. Frequency measurement in DNP3 fault record corrected	Patch for V2.14 Studio ftp server	P44y/EN M/C32 + addendum P44y/EN AD/D32
57	C	K	05-May-2010	Release of P543 61850 with distance protection based on 57B Enhancement to GOOSE performance Fixes to 61850. Fixed Protection comms address problem in three ended scheme selected Fixed dnp3 control of CB2 Fixed a small issue with the detection of slow swings	Patch for V2.14 Studio ftp server	P44y/EN M/C32 + addendum P44y/EN AD/D32

Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	**Minor**					
57	D	K	15-Oct-2010	Release of P44y (P443 and P446) with distance protection based on 57B Enhancement to GOOSE performance Fixes to 61850. Fixed Protection comms address problem in three ended scheme selected Fixed dnp3 control of CB2 Fixed a small issue with the detection of slow swings Incorrect mapping of XCBR(n).CBOpCap.stVal data attribute corrected Time stamping and status of IEC61850 Data attribute sofPSOF1.ST.general.Op improved Enhanced the OST feature to make it more stable when currents are low Improved the distance performance for cross country faults Improvements to Fault record display over courier and dnp3	Patch for V2.14 Studio ftp server	P44y/EN M/C32 + addendum P44y/EN AD/D32
57	E	K	11-Jan-2011	Release of P44y (P443 and P446) with distance protection based on 57D Rebranded as Alstom. Minor change to software number plus changes to 61850 (New ICD files required)	Patch for V2.14 Studio ftp server	P44y/EN M/C32 + addendum P44y/EN AD/D32
57	U	K	23-Feb-2011	Release of P44y (P443 and P446) with distance protection based on 57D Rebranded as Schneider Electric. Minor change to software number. Changes to 61850 (New ICD files required). Changes to improve IEC61850 reporting on rapidly toggling status. Corrections to IEC61850 datamodel. Improvements to processing of GOOSE messages when using managed Ethernet switch parameterised for VLAN. Improvements to PSL Operation when non-latched and latched LEDs are used together. Improvements to copro configuration (settings) failure detection. Improvements to Zone 1 Extension Reset. P543 Software Version 47 only - Corrected PSL Reference Cell in the PSL DATA menu column. Bug Fixes.	Studio ftp server	P44y/EN M/C32 + addendum P44y/EN AD/D32
57	V	K	17-Jun-2011	Release of P44y (P443 and P446) with distance protection based on 57U CB Fail reset time on fault clearance improvement. CB Status monitoring improvement	Studio ftp server	P44y/EN M/C32 + addendum P44y/EN AD/D32

Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	Minor					
57	W	K	27-Dec-2011	Release of P44y (P443 and P446) with distance protection based on 57V Status report over IEC61850 not in line with DDB signals OST sensitivity now 60mA (was previously 180mA). Protection communications Invalid Message Format Alarm Implementation corrected. Directional negative sequence overcurrent will only reset from the tripped state by loss of current and not incorrect direction. Improved IEC61850 Status reporting of DDB signal changes. The default PSL of P546 with 12 high break outputs could not upload from relay correctly. The options with 20 relays outputs associate the default PSL with 32 relays outputs. P544/P546 57V IEC61850 + CS103 variant Download: Relay does not occasionally re-boot with error code 0X351f03f5. BugFixes	Studio ftp server	P44y/EN M/C32 + addendum P44y/EN AD/D32
57	X	K	15-May-2012	Release of P44y (P443 and P446) with distance protection based on 57W Improved IEC61850 Goose Performance Distance zone 1 may mal-trip when simulated three-phase VT fail condition is applied. Improvements to IEC61850. Bug Fixes.	Studio ftp server	P44y/EN M/C32 + addendum P44y/EN AD/D32
B0	A	K	09-Nov-2011	Release of P44y (P443 and P446) with distance protection based on 57U (Courier, CS103 and IEC61850+Courier Comms protocols only). Change to Schneider Electric Major release (alpha) software number plus changes to 61850 (New ICD files required). Changes to improve IEC61850 reporting on rapidly toggling status. Corrections to IEC61850 datamodel. CB Fail reset time on fault clearance improvement. Enhanced Disturbance Recorder - 20 Analog / 128 Digital Channels. Additional Differential, Max Bias and 2nd Harmonic current data. CT Ratio Enhancements (P544/P546 allow use of different CT1 and CT2 Ratios). Additional CB Monitoring data provided over CS103. OST sensitivity now 60mA (was previously 180mA). Protection communications Invalid Message Format Alarm Implementation corrected. Language Text for "IED CONFIGURATOR" menu column header uses selected language (previously only English). Bug Fixes.	Studio ftp server	P44y/EN M/C32 + addendum P44y/EN AD/D32 or P44y/EN M/D32

Software Version		Hardware Suffix	Original Date of Issue	Description of Changes	S1 Compatibility	Technical Documentation
Major	**Minor**					
B0	B	K	31-May-2012	Release of P44y (P443 and P446) with distance protection based on B0A. DR code optimize to release additional memory for DR pre-trigger time. Additional protocols release (DNP3, DNP3OE, IEC61850+IEC103) by compare with A0/B0A. Improved IEC61850 Goose Performance. Changes to improve IEC61850 reporting on rapidly toggling status. Status report over IEC61850 not in line with DDB signals Schneider use alpha character for software release version. Major version is not compatible with letters of cs103 protocol, both IED code and tools. Bug Fixes	Studio ftp server	P44y/EN M/C32 + addendum P44y/EN AD/D32 or P44y/EN M/D32
D0	A	M	June 2012	Cyber Security	Studio ftp server	P44y/EN M/C32 + addendum P44y/EN AD/D32 + addendum P44y/EN AD/E63 or P44y/EN M/E63

Table 1 - Version History (software versions and hardware suffix)

2 SETTING FILE SOFTWARE VERSION

Setting file software version	Relay software version											
	20	**30**	**31**	**32**	**33**	**51**	**52**	**54**	**55**	**57**	**B0**	**D0**
20	✓	×	×	×	×	×	×	×	×	×	×	×
30	×	✓	✓	×	×	×	×	×	×	×	×	×
31	×	✓	✓	×	×	×	×	×	×	×	×	×
32	×	×	×	✓	×	×	×	×	×	×	×	×
33	×	×	×	×	✓	×	×	×	×	×	×	×
51	×	×	×	×	×	✓	×	×	×	×	×	×
52	×	×	×	×	×	×	✓	×	×	×	×	×
54	×	×	×	×	×	×	×	✓	×	×	×	×
55	×	×	×	×	×	×	×	×	✓	×	×	×
57	×	×	×	×	×	×	×	×	×	✓	×	×
B0	×	×	×	×	×	×	×	×	×	×	✓	×
D0	×	×	×	×	×	×	×	×	×	×	×	✓

Table 2 - Setting file software and relay software versions

3 PSL FILE SOFTWARE VERSION

PSL file software version	Relay software version											
	20	30	31	32	33	51	52	54	55	57	B0	D0
20	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
30	✗	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗
31	✗	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗
32	✗	✗	✗	✓	✗	✗	✗	✗	✗	✗	✗	✗
33	✗	✗	✗	✗	✓	✗	✗	✗	✗	✗	✗	✗
51	✗	✗	✗	✗	✗	✓	✗	✗	✗	✗	✗	✗
52	✗	✗	✗	✗	✗	✗	✓	✗	✗	✗	✗	✗
54	✗	✗	✗	✗	✗	✗	✗	✓	✗	✗	✗	✗
55	✗	✗	✗	✗	✗	✗	✗	✗	✓	✗	✗	✗
57	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓	✗	✗
B0	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓	✗
D0	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓

Table 3 - PSL file software version and relay software versions

4 MENU TEXT FILE SOFTWARE VERSION

Menu text file software version	Relay software version											
	20	30	31	32	33	51	52	54	55	57	B0	D0
20	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
30	✗	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
31	✗	✗	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗
32	✗	✗	✗	✓	✗	✗	✗	✗	✗	✗	✗	✗
33	✗	✗	✗	✗	✓	✗	✗	✗	✗	✗	✗	✗
51	✗	✗	✗	✗	✗	✓	✗	✗	✗	✗	✗	✗
52	✗	✗	✗	✗	✗	✗	✓	✗	✗	✗	✗	✗
54	✗	✗	✗	✗	✗	✗	✗	✓	✗	✗	✗	✗
55	✗	✗	✗	✗	✗	✗	✗	✗	✓	✗	✗	✗
57	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓	✗	✗
B0	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓	✗
D0	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓

Table 4 - Menu text file software version and relay software versions

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